Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

May 19th, 2021

(data current to May 15th – May 18th)

Biocomplexity Institute Technical report: TR 2021-059

UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE

biocomplexity.virginia.edu

About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others

Points of Contact

Bryan Lewis
brylew@virginia.edu

Srini Venkatramanan
srini@virginia.edu

Madhav Marathe
marathe@virginia.edu

Chris Barrett
ChrisBarrett@virginia.edu

Model Development, Outbreak Analytics, and Delivery Team

Przemyslaw Porebski, Joseph Outten, Brian Klahn, Alex Telionis, Srinivasan Venkatramanan, Bryan Lewis, Aniruddha Adiga, Hannah Baek, Chris Barrett, Jiangzhuo Chen, Patrick Corbett, Stephen Eubank, Ben Hurt, Dustin Machi, Achla Marathe, Madhav Marathe, Mark Orr, Akhil Peddireddy, Asal Pilehvari, Erin Raymond, James Schlitt, Anil Vullikanti, Lijing Wang, James Walke, Andrew Warren, Amanda Wilson, Dawen Xie

UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project based on scenarios for next 4 months
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

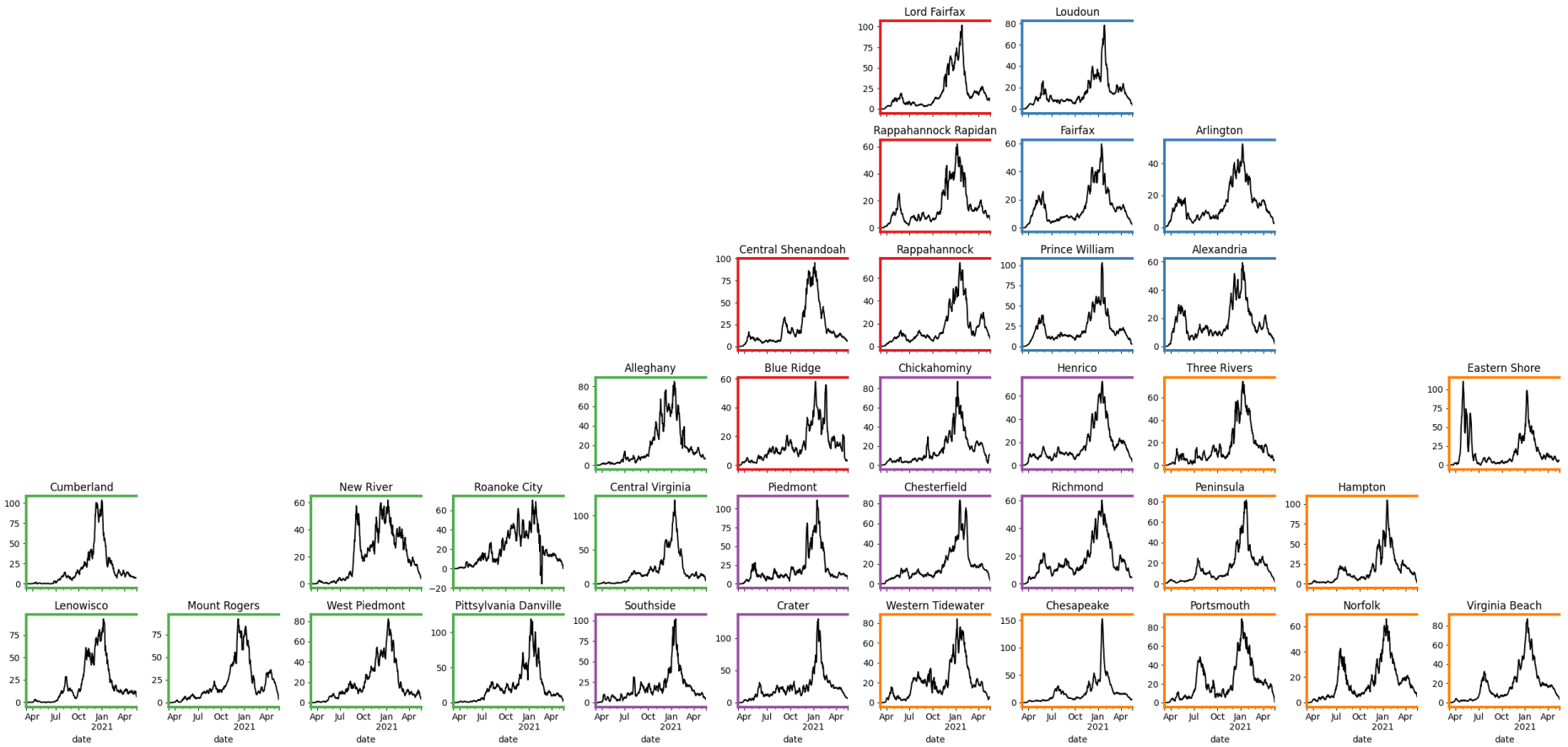
Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

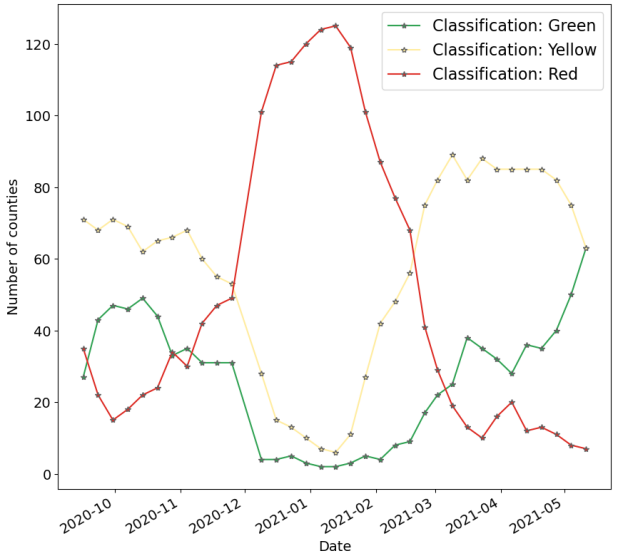
- **Case rates in Virginia continue to decline with pace accelerating in some districts**
- VA mean weekly incidence down to 6/100K from 8/100K, US down (10 from 12 per 100K)
- Vaccination rates have slowed considerably, but population immunity now estimated over 60%
- Projections show declining rate overall across Commonwealth
- Recent updates:
  - Minor updates to measured acceptance levels, validated with additional national survey
  - Minor update to Fatigued Control scenario, with quicker time to full fatigue and limits on duration
  - Added vaccination scenarios to compare status quo acceptance levels against expanded optimistic levels

The situation continues to change. Models continue to be updated regularly.

Situation Assessment

Case Rates (per 100k) and Test Positivity





https://data.cms.gov/stories/s/q5r5-gjyu

County level test positivity from RT-PCR tests.

Green: <5.0%
(or with <20 tests in past 14 days)

Yellow: 5.0%-10.0%
(or with <500 tests and <2000 tests/100k and >10% positivity over 14 days

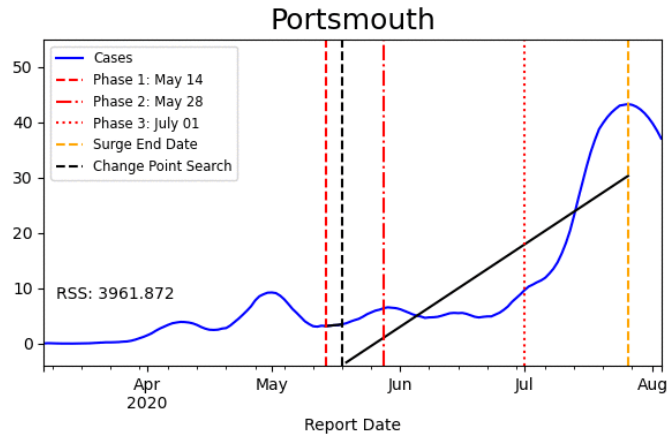
Red: >10.0%
(and not "Green" or "Yellow")

District Trajectories

Goal: Define epochs of a Health District's COVID-19 incidence to characterize the current trajectory

Method: Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period's slope to define the trajectory

Hockey stick fit

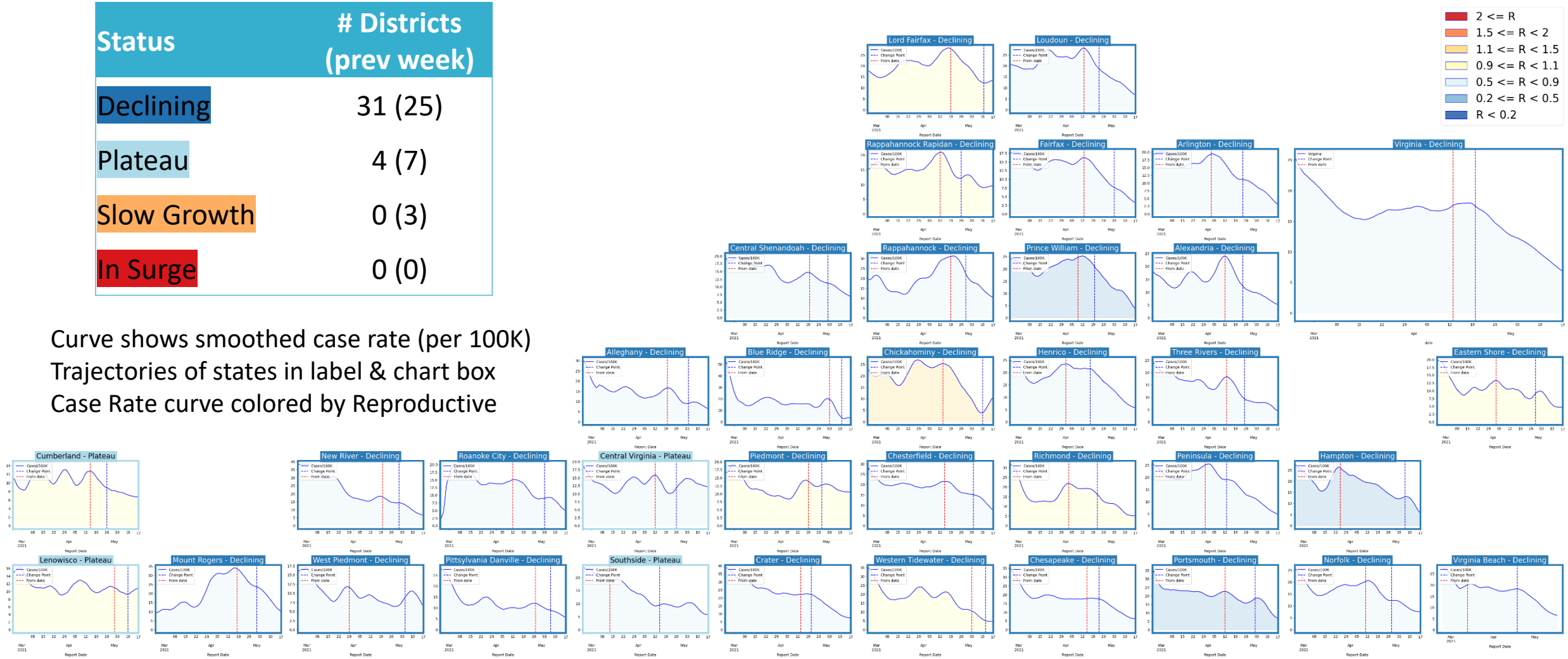


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (prev week)
Declining	Sustained decreases following a recent peak	below -0.9	25 (24)
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5	7 (5)
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	3 (6)
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater	0 (0)

District Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	31 (25)
Plateau	4 (7)
Slow Growth	0 (3)
In Surge	0 (0)

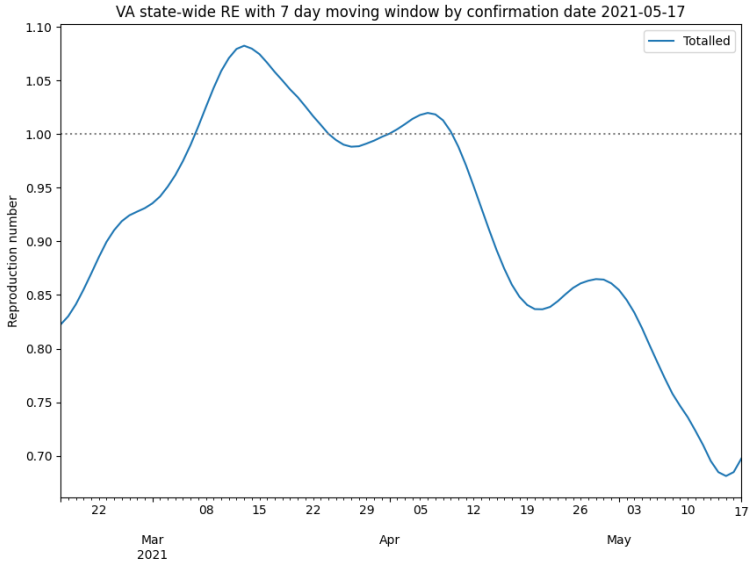
Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive

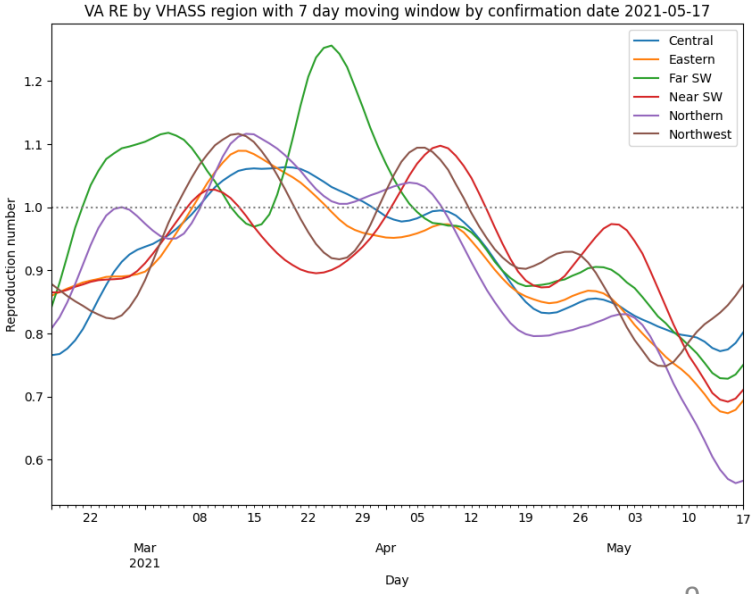


Estimating Daily Reproductive Number

May 17th Estimates

Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.697	-0.080
Central	0.802	0.030
Eastern	0.694	-0.064
Far SW	0.750	-0.034
Near SW	0.711	-0.200
Northern	0.567	-0.281
Northwest	0.877	0.231





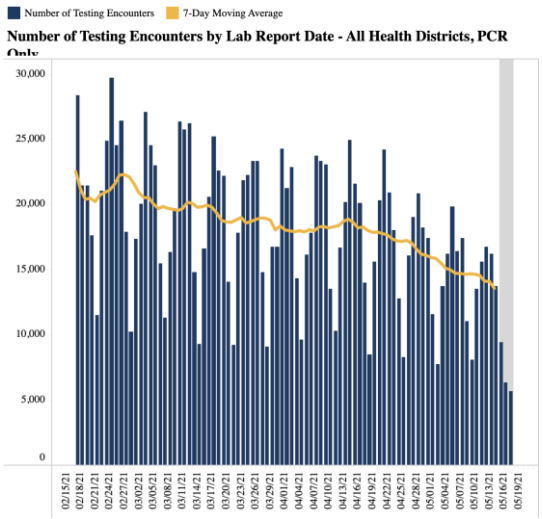
Methodology

- Wallinga-Teunis method (EpiEstim[1]) for cases by **confirmation date**
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

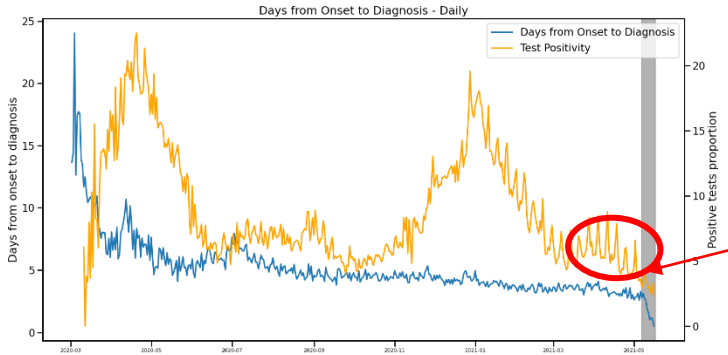
Changes in Case Detection

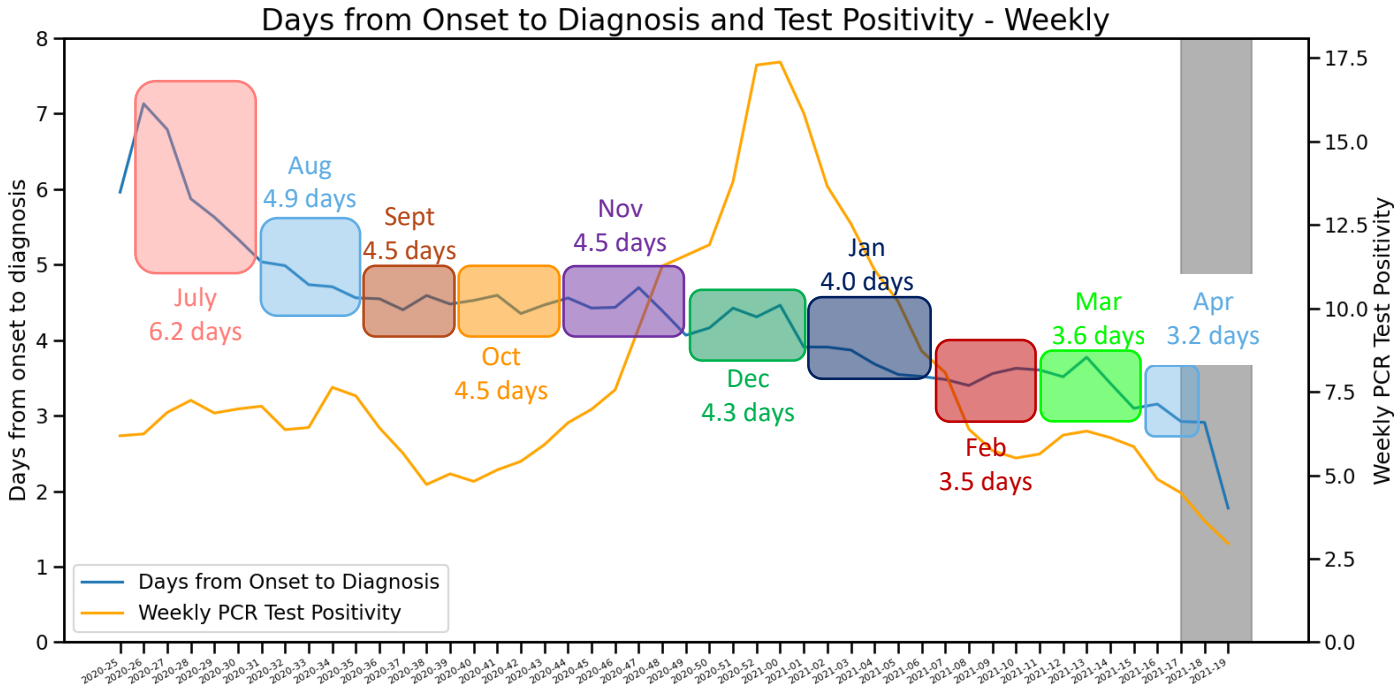
Timeframe (weeks)	Mean days	% difference from overall mean
July (26-30)	6.2	-3%
Aug (31-34)	4.9	-23%
Sept (35-38)	4.5	-29%
Oct (39-43)	4.5	-29%
Nov (44-47)	4.5	-29%
Dec (48-49)	4.3	-33%
Jan (00-04)	4.0	-37%
Feb (05-08)	3.5	-45%
Mar (09-13)	3.6	-43%
Apr (14-17)	3.2	-50%
Overall (13 - 17)	6.3	--



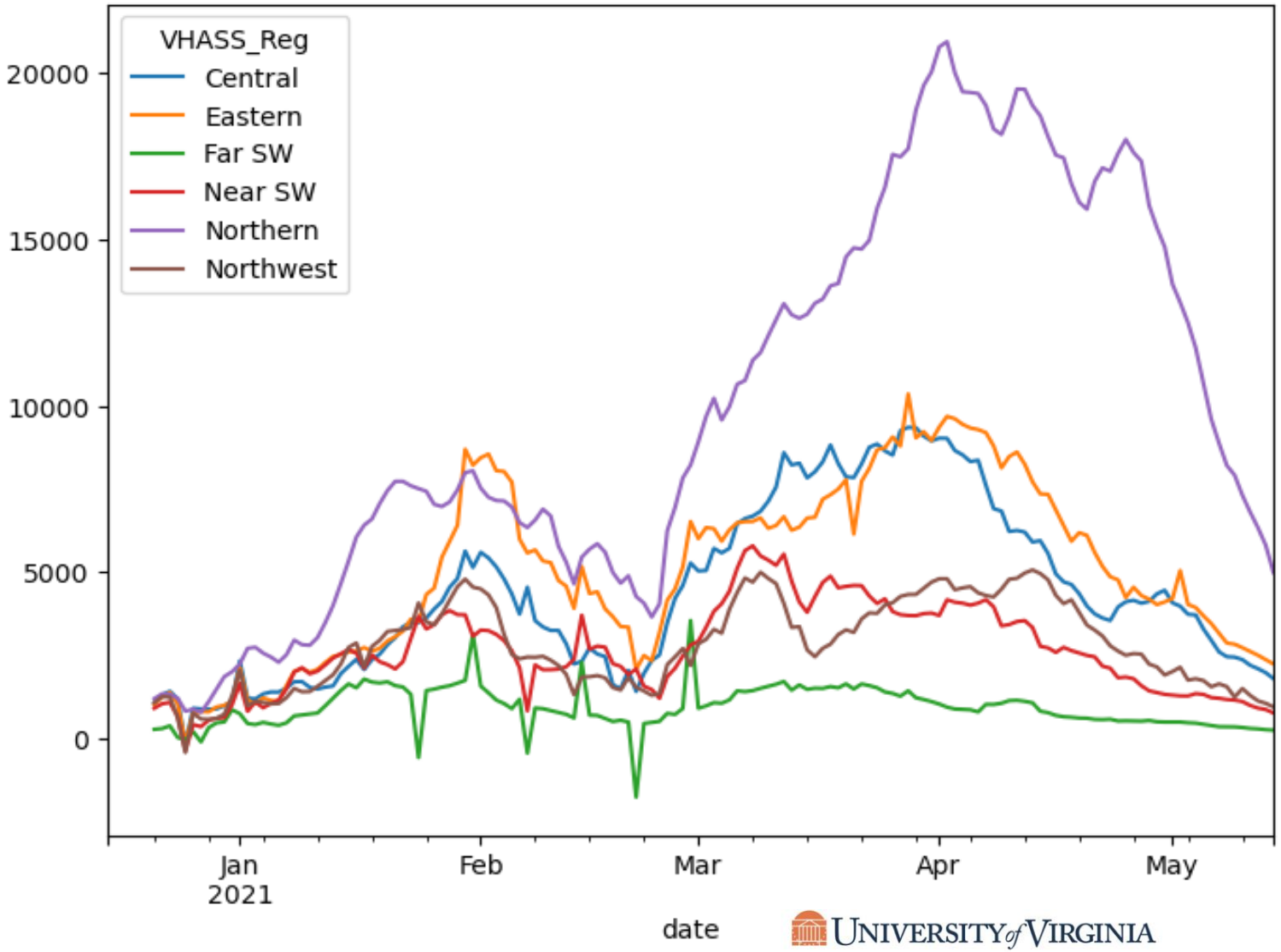
Accessed 9:00am May 19, 2021
https://www.vdh.virginia.gov/coronavirus/

Test positivity vs. Onset to Diagnosis



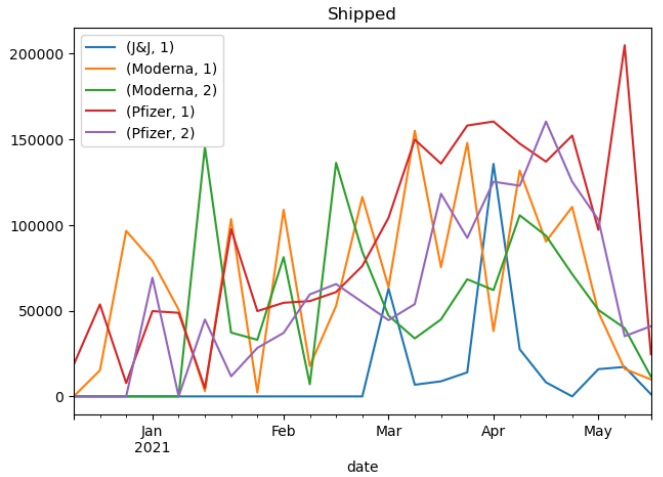


Vaccination Administration Slows



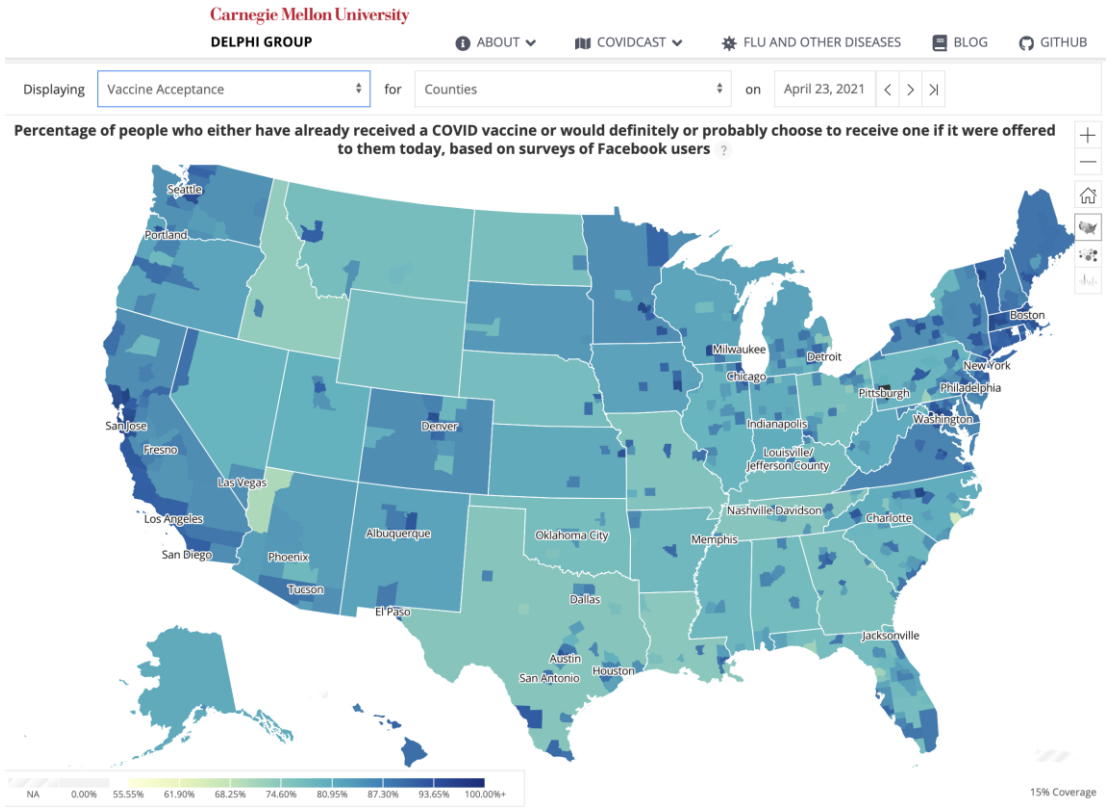
Regional Vaccine courses initiated per day:

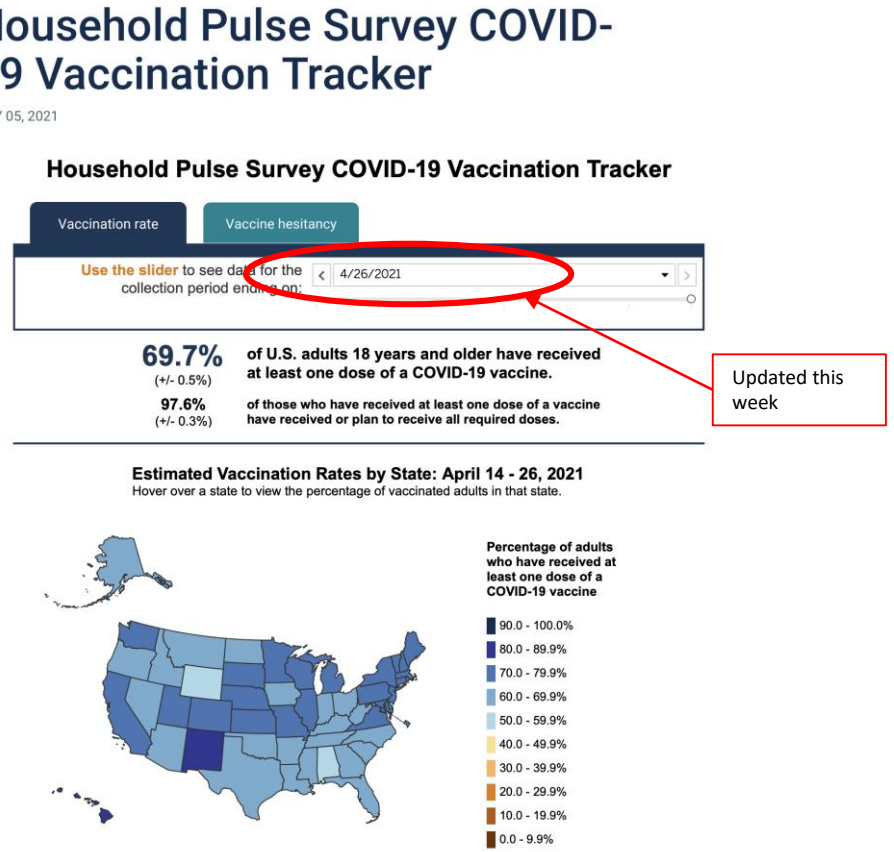
- Total counts of first dose of vaccines across regions
- Significant declines starting at the end of April



Shipments remain relatively high across the state

Vaccine Acceptance Data Sources





COVIDcast / Facebook Survey

https://covidcast.cmu.edu

Census Household Pulse Surveys (HPS)

https://www.census.gov/library/visualizations/interactive/household-pulse-survey-covid-19-vaccination-tracker.html

UNIVERSITY of VIRGINIA

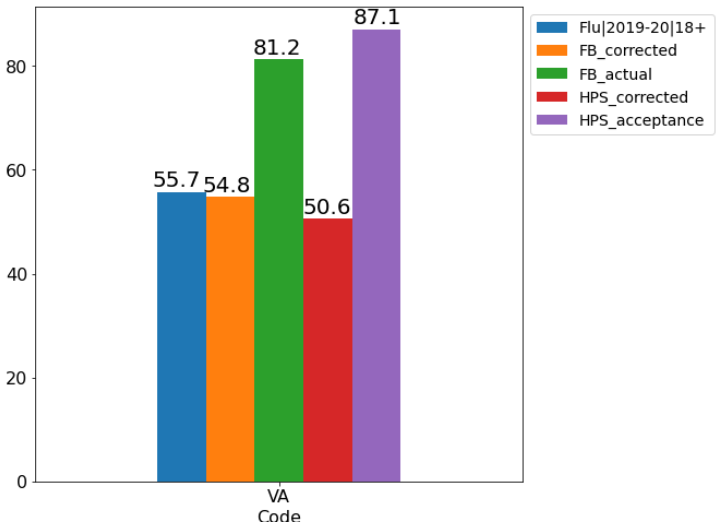
BIOCOMPLEXITY INSTITUTE

Vaccination Acceptance – Comparison of Sources

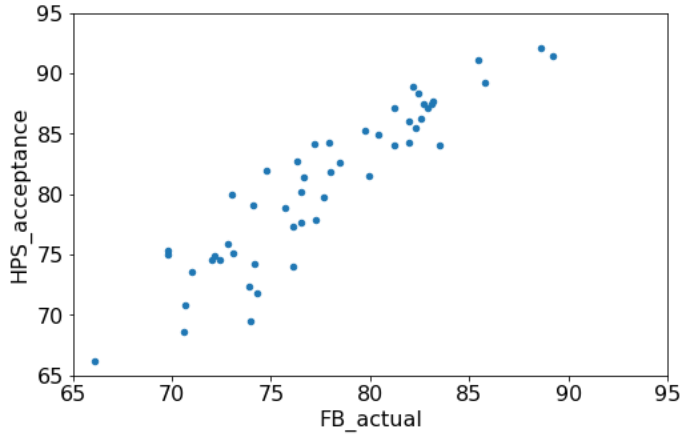
Measured acceptance varies across sources:

- **COVIDcast / Facebook (FB):** Both corrected and actual measurement
- **FluVax:** Acceptance levels in VA for influenza vaccine during 2019-20 flu season
- **Household Pulse (HPS):** Census administered survey, but with some time delay till release (most recent for fortnight ending April 26th, 2021)
- HPS has highest overall, while FluVax is expectedly the lowest
- Corrected HPS and COVIDcast are very similar for VA at the state level, and approach FluVax

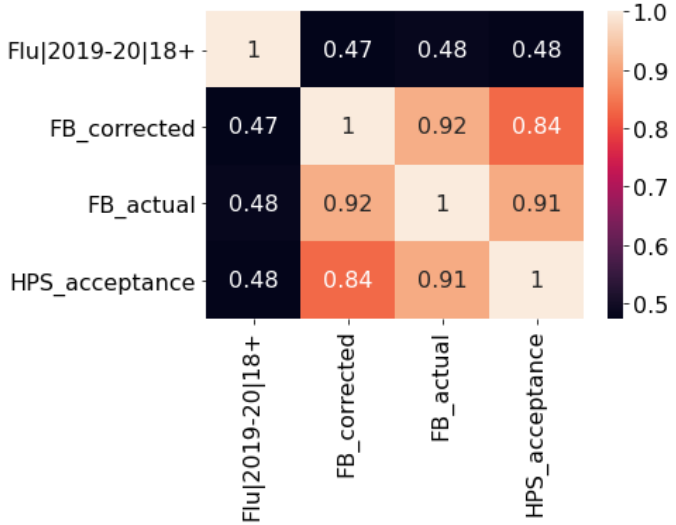
Virginia Vaccine Acceptance levels



State by State correlation COVIDcast and HPS



State level correlation between all four



UNIVERSITY of VIRGINIA

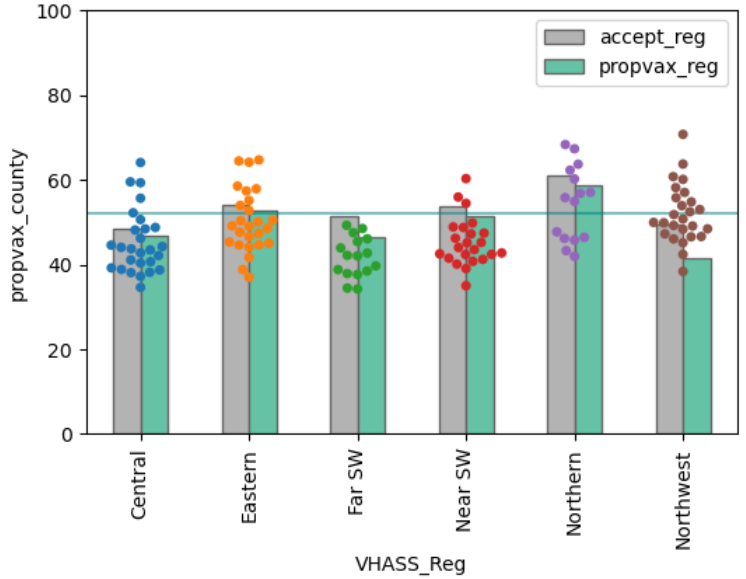
BIOCOMPLEXITY INSTITUTE

Vaccination Acceptance by Region

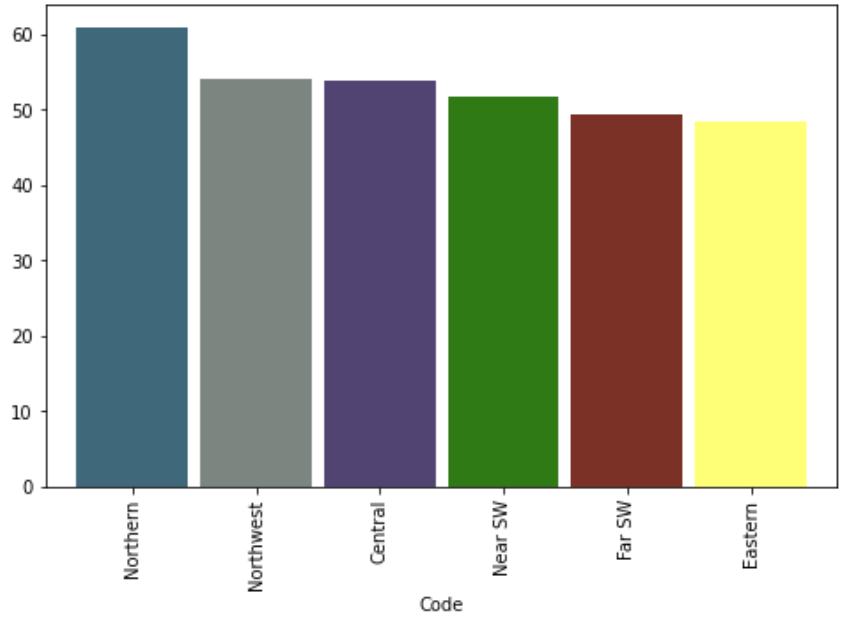
Corrections to COVIDcast survey:

- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

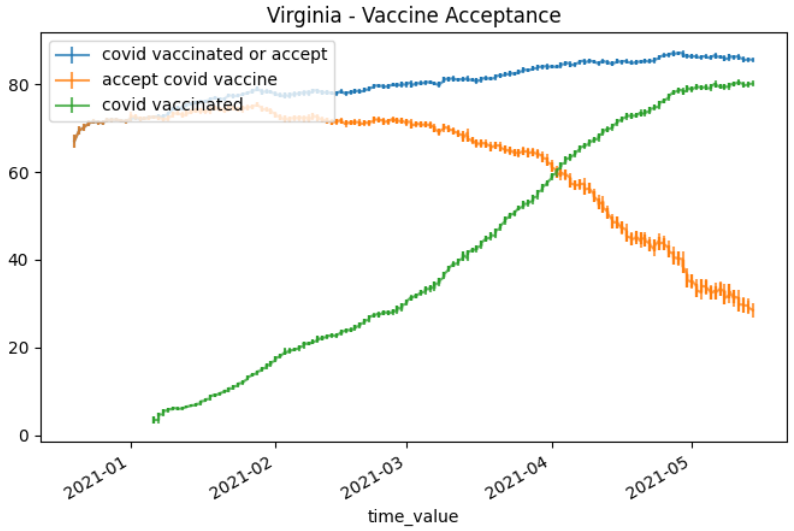
Region	COVIDcast corrected	COVIDcast uncorrected	VDH proportion vaccinated	COVIDcast reported vaccinated
Northern	61%	86%	59%	81%
Central	54%	77%	52%	72%
Northwest	54%	77%	53%	75%
Near SW	52%	76%	47%	71%
Eastern	48%	77%	47%	74%
Far SW	49%	70%	41%	62%

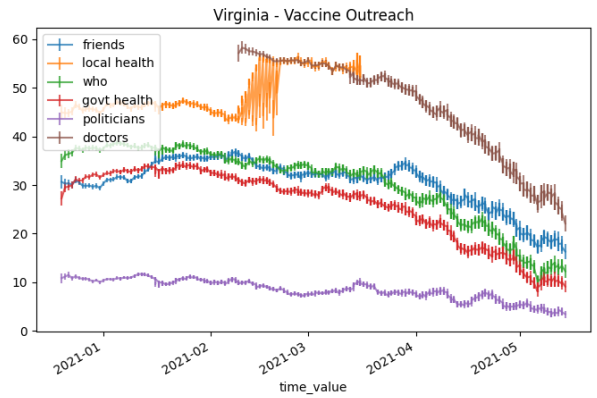


Bars: Survey measured and corrected acceptance by region & proportion of eligible population administered a vaccine
Dots: Proportion administered at least one dose for each county



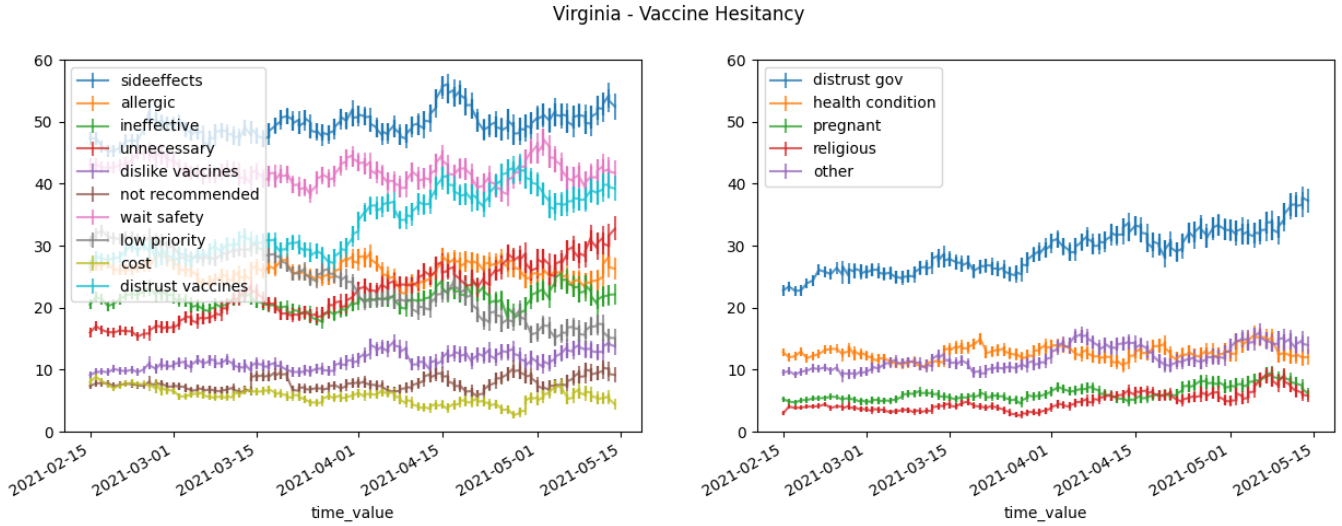
Vaccine Acceptance in Virginia - COVIDcast





Acceptance remains high:

- Proportion of Virginians that have already or would definitely or probably accept vaccination if offered today
- *Survey respondents are reporting high levels of vaccination of ~70% reflecting some bias of the mechanism*
- Over 80% of Virginians have already or will choose to be vaccinated
- **Top reasons for hesitancy**: side effects, safety, distrust (increasing)
- **More likely to take if recommended by** doctors and friends



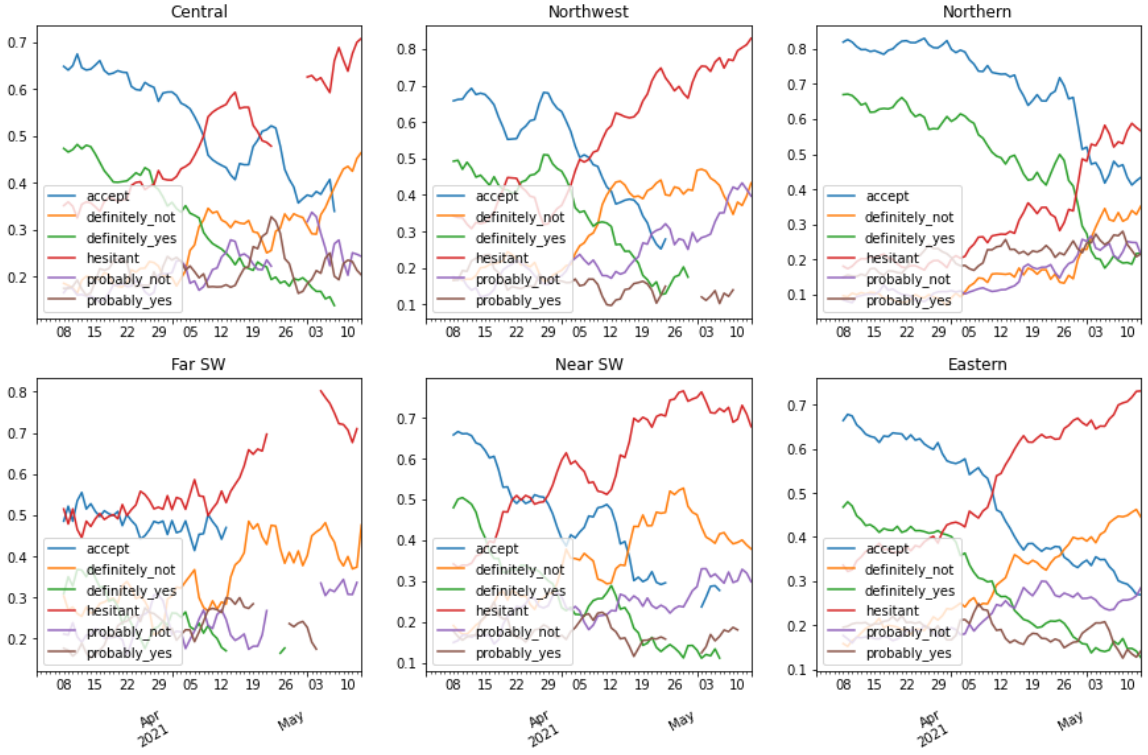
Data Source: https://covidcast.cmu.edu

Vaccine Acceptance by Region- COVIDcast

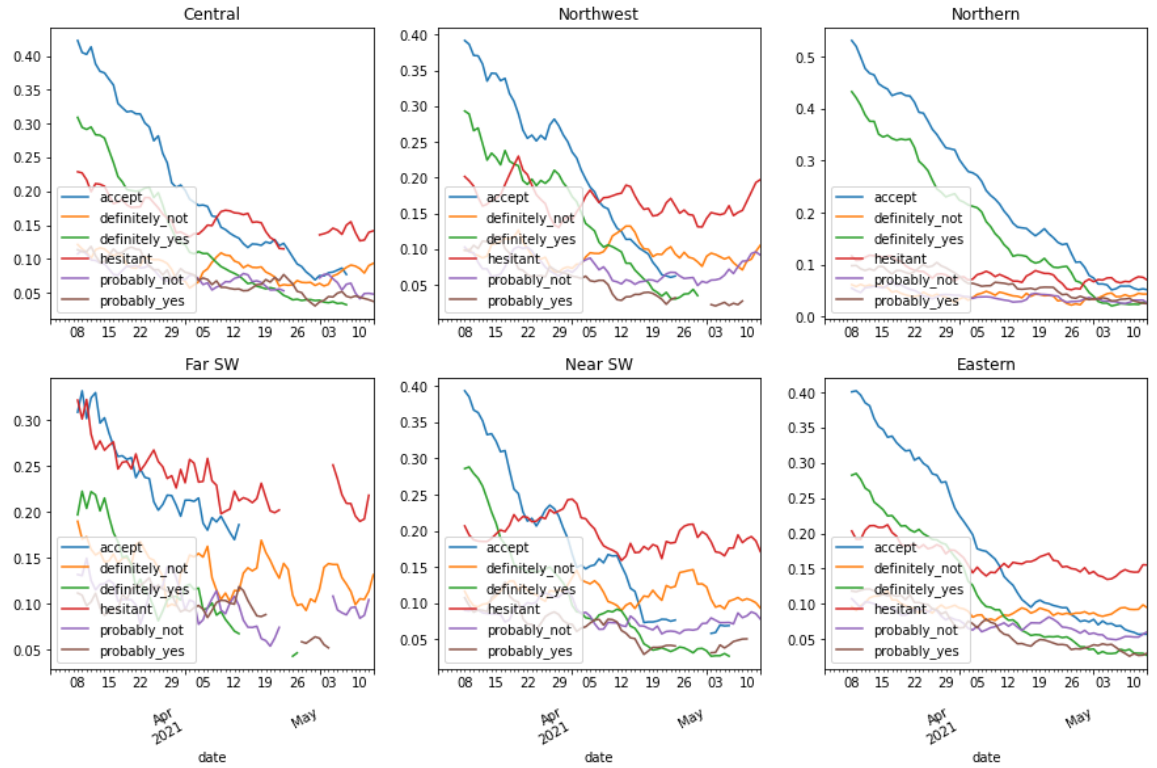
Levels of Acceptance and potential acceptance in flux:

- Nearly all the “Definitely Yes” have been vaccinated, yet there are 5-10% remaining across the regions
- Northwest and Southwest (to lesser degree) see growth in “probably not”, seemingly from “definitely not”

Unvaccinated Only



All Respondents

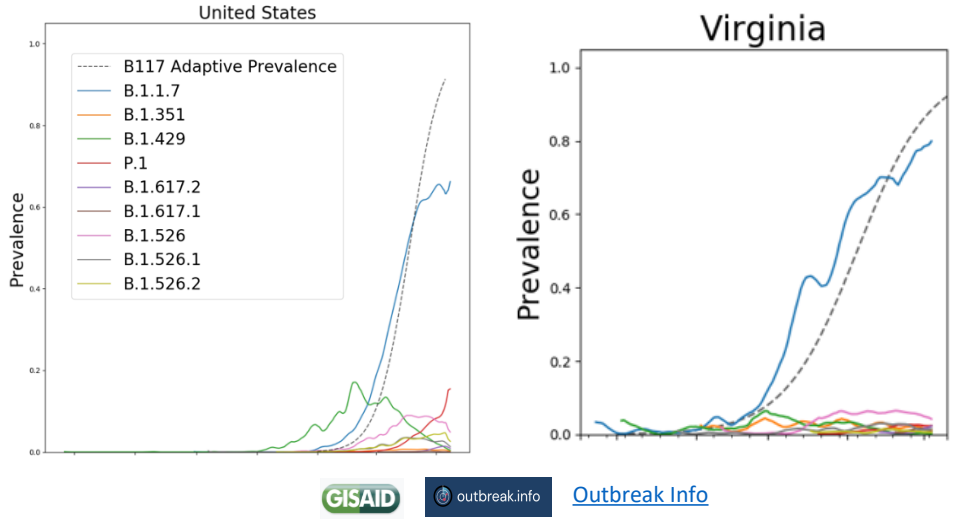


Data Source: https://covidcast.cmu.edu

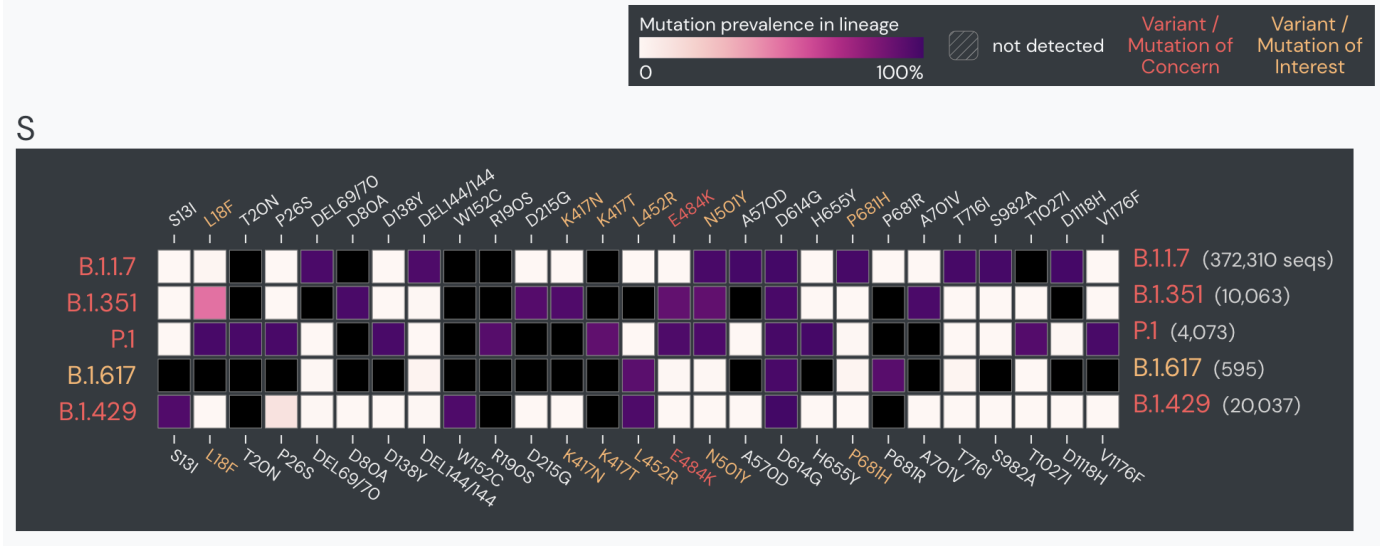
SARS-CoV2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control

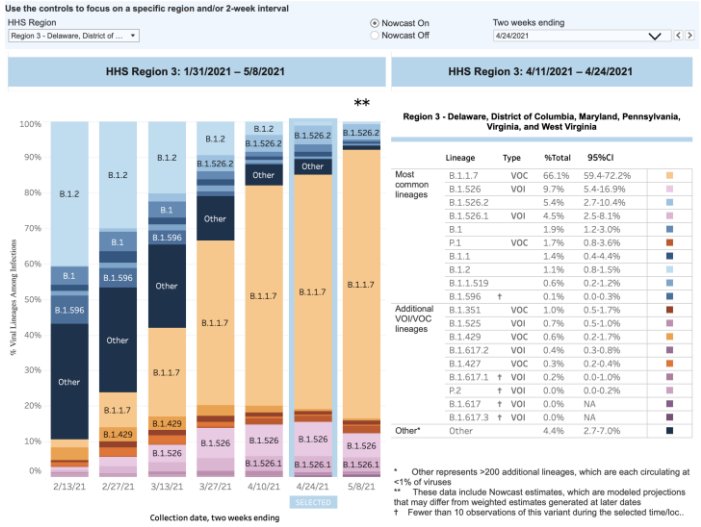
- Emerging variants can:
  - Increase transmissibility
  - Increase severity (more hospitalizations and/or deaths)
  - Limit immunity provided by prior infection and vaccinations
- Genomic surveillance remains very limited
  - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future



GISAID outbreak.info [Outbreak Info](#)



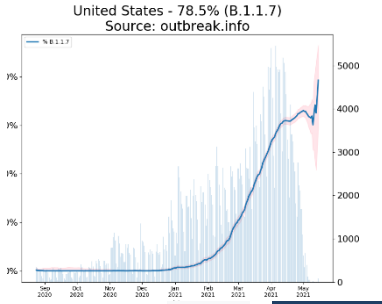
outbreak.info [Outbreak Info](#)

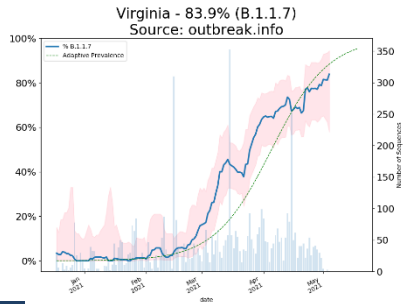


CDC [CDC Variant Tracking](#)

SARS-CoV2 Variants of Concern

Lineage B.1.1.7





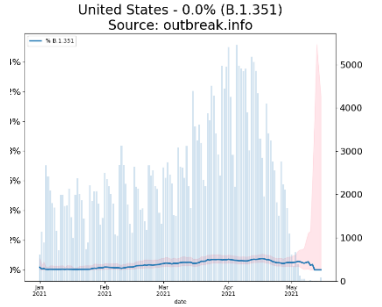
GISAID outbreak.info [Outbreak Info](#)

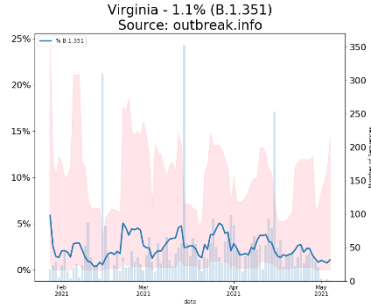
Prevalence: Levels have rapidly risen, as anticipated, and now are plateauing at national level and in many states, seemingly in VA as well

Transmissibility: Estimated increase of 50% compared to previous variants. B.1.1.7's mutations aids its infection efficiency, and thus boosts its overall levels of viremia; study from Public Health England shows contacts of B.1.1.7 cases are more likely (50%) to test positive than contacts of non-B.1.1.7 patients

Severity: Increased viremia also appears to increase the risk of hospitalization (60%) and mortality (60%). Danish study shows B.1.1.7 to have a 64% higher risk of hospitalization, while Public Health Scotland studies showed a range of 40% to 60%; Study in Nature based on UK data estimates B.1.1.7 cases have 60% higher mortality

Lineage B.1.351





Prevalence: Levels have remained low, as this variant's transmissibility can't compete with B.1.1.7, however, as more of the population becomes immune it may gain an advantage

Immune Escape: Many studies show that convalescent sera from previously infected individuals does not neutralize B.1.351 virus well which is predictive of protection, however, vaccine induced immunity shows signs of effectiveness

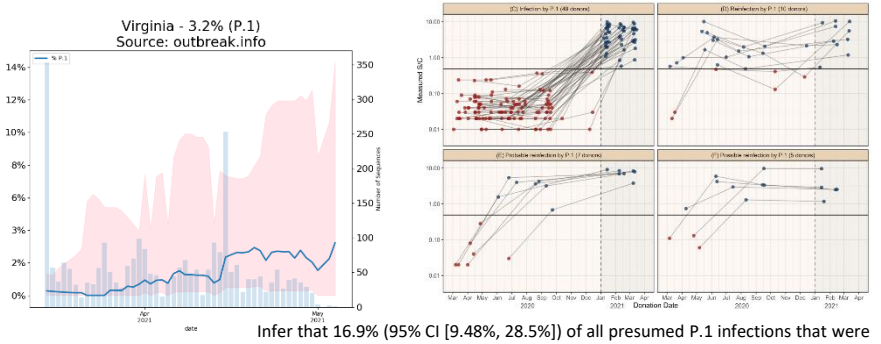
Lineage B.1.429/427 and B.1.526 and subvariants

- Combined account for around 20% of circulating virus, share may be shrinking as B.1.1.7 outcompetes

SARS-CoV2 Variants of Concern

Lineage P.1

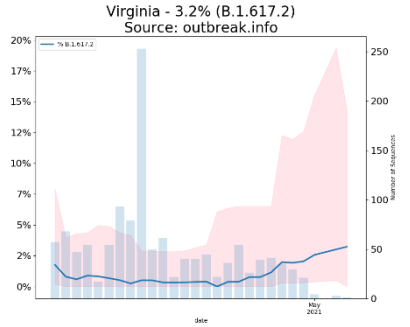
- **Prevalence:** Nationally at 13.2%, though lower in VA at 3.2%
- New study estimates 17-32% of all infections in Manaus in 2021 were reinfections, which helps explain data from Brazil demonstrating P.1's continued dominance in Rio despite presence of B.1.1.7

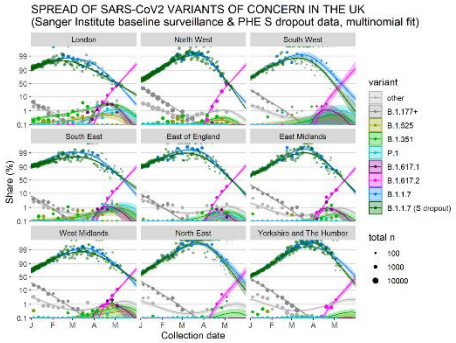


Infer that 16.9% (95% CI [9.48%, 28.5%]) of all presumed P.1 infections that were observed in 2021 were reinfections. Including probable or possible reinfections this expand to 25.8% (95% CI [16.7%, 37.4%]), and 31.0% (95% CI [21.4%, 42.5%]). medRxiv

Lineage B.1.617.2 and subvariants B.1.617.2 & B.1.617.1

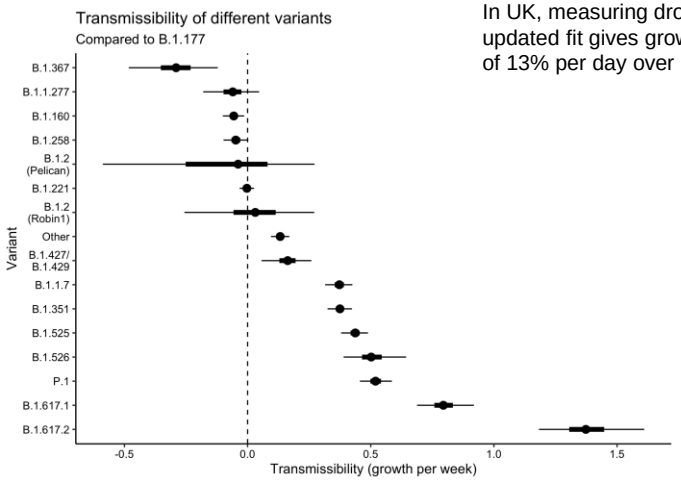
- Continues to drive outbreak in India and neighbors, with immeasurable numbers of cases surpassing healthcare capacities in many regions
- Categorized as VoC by Public Health England, WHO, expect CDC to follow
- Strain shows continued growth in UK, Europe and lesser extent in US



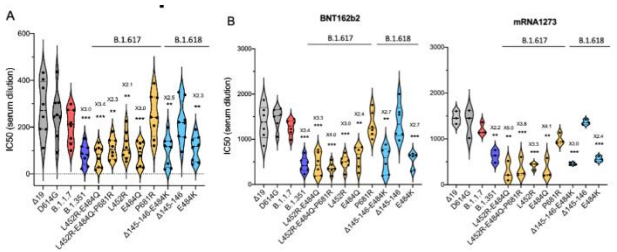


In UK, measuring drop in B.1.1.7 and updated fit gives growth rate advantage of 13% per day over B.1.1.7 Twitter

- Several studies estimate B.1.617.2 to have 100% faster growth than B.1.1.7, and UK study suggests a 13% advantage over B.1.1.7
- More studies show limited immune escape similar to B.1.351, however, still suggest protection remains for vaccinated

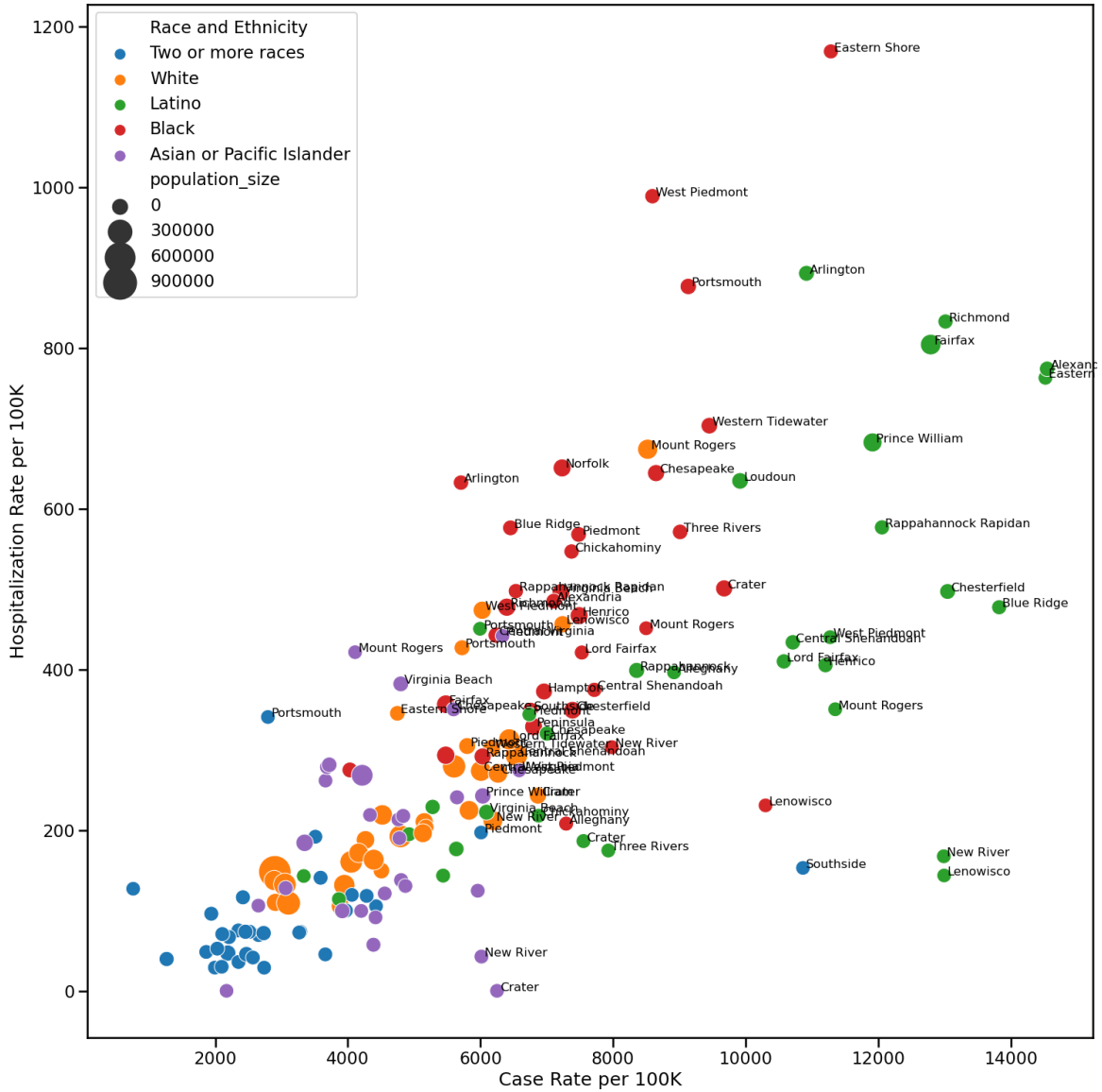


Multi country analysis to assess the relative advantages of different variants relative to B.1.1.7. Biases likely influence it but nonetheless, B.1.617.2 is highest Twitter



Viruses with B.1.617 and B.1.618 spike required more sera to be neutralized (2-5-fold decrease in titer by convalescent sera and vaccine-elicited antibodies). Similar levels for E484Q and E484K. The modest neutralization resistance of the variant spike proteins to vaccine elicited antibody suggests that current vaccines will remain protective against the B.1.617 and B.1.618 variants bioRxiv

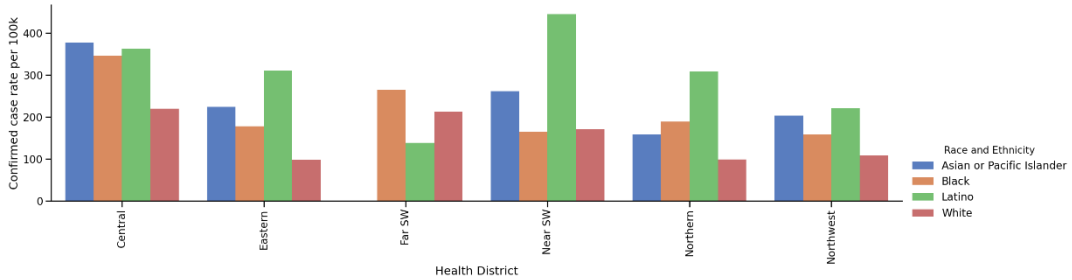
Race and Ethnicity cases per 100K



Rates per 100K of each Racial-Ethnic population by Health District

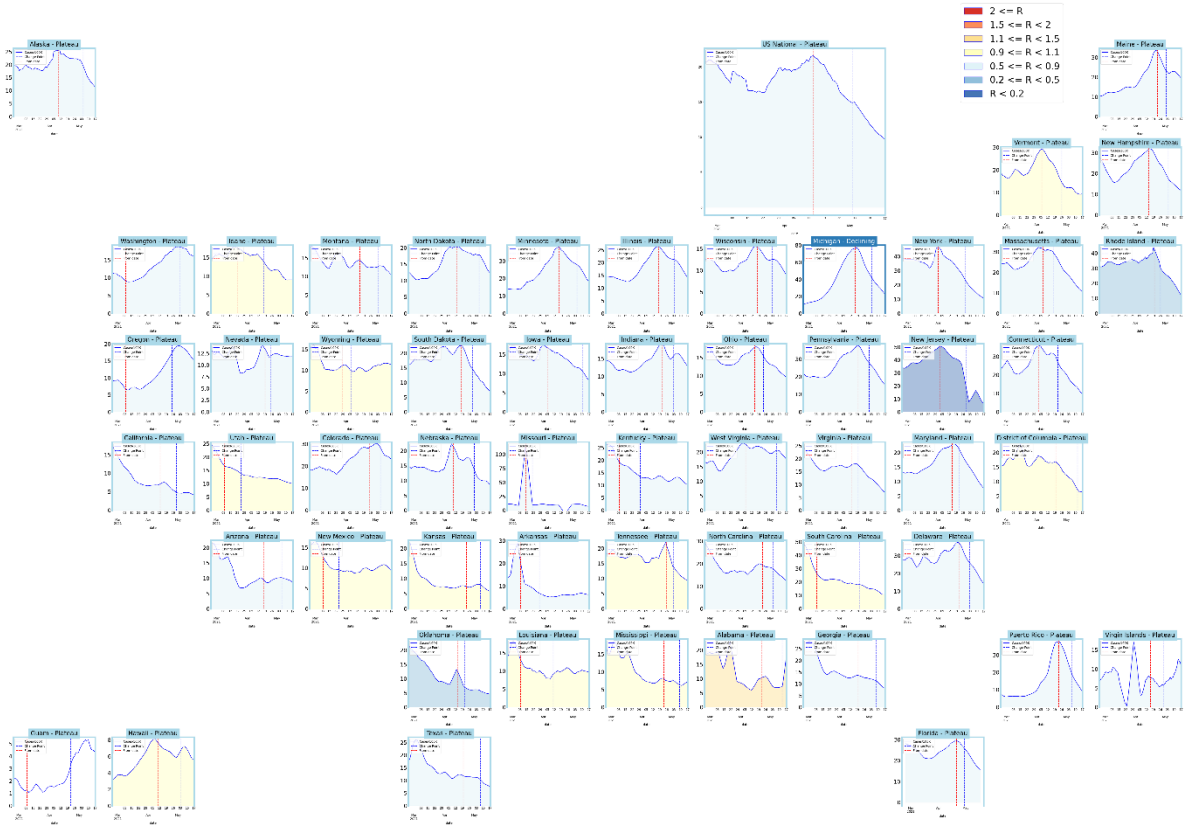
- Each Health District's Racial-Ethnic population is plotted by their Hospitalization and Case Rate
- Points are sized based on their overall population size (overlapping labels removed)
- Change in rates over the last 2 weeks

Case Rate Change in last 14 days



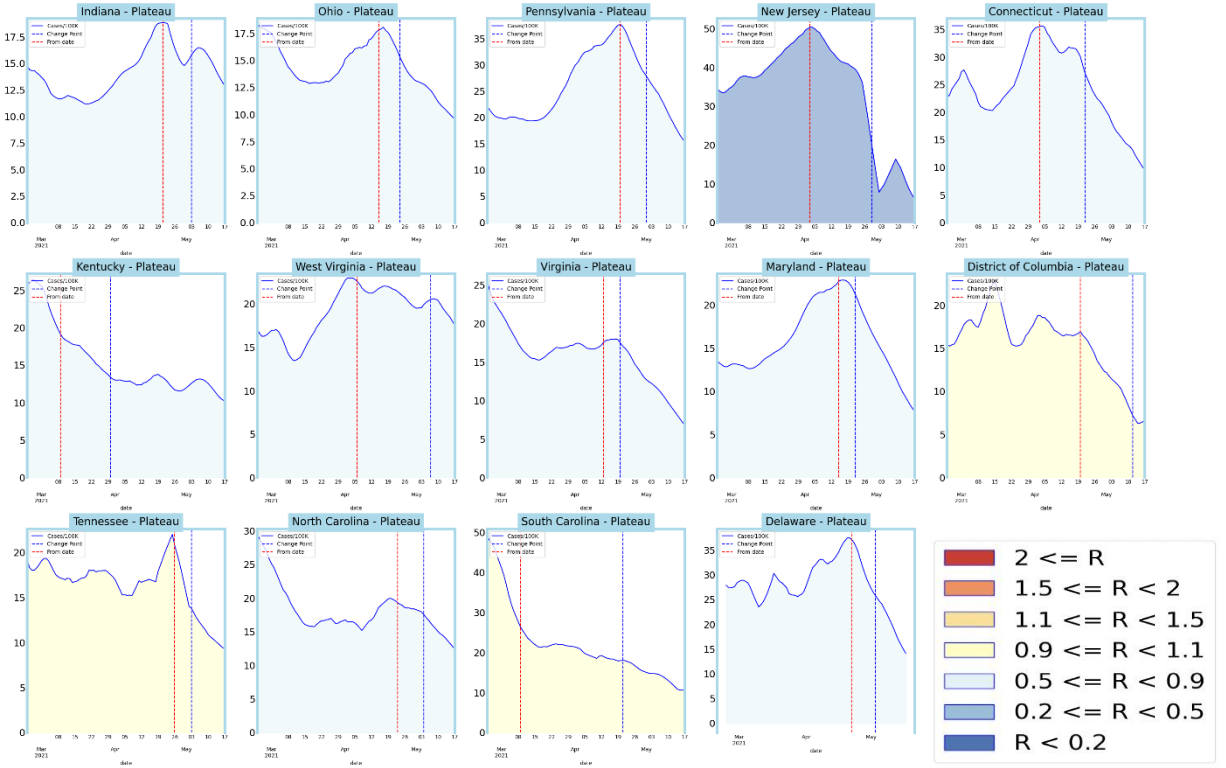
Other State Comparisons

Trajectories of States



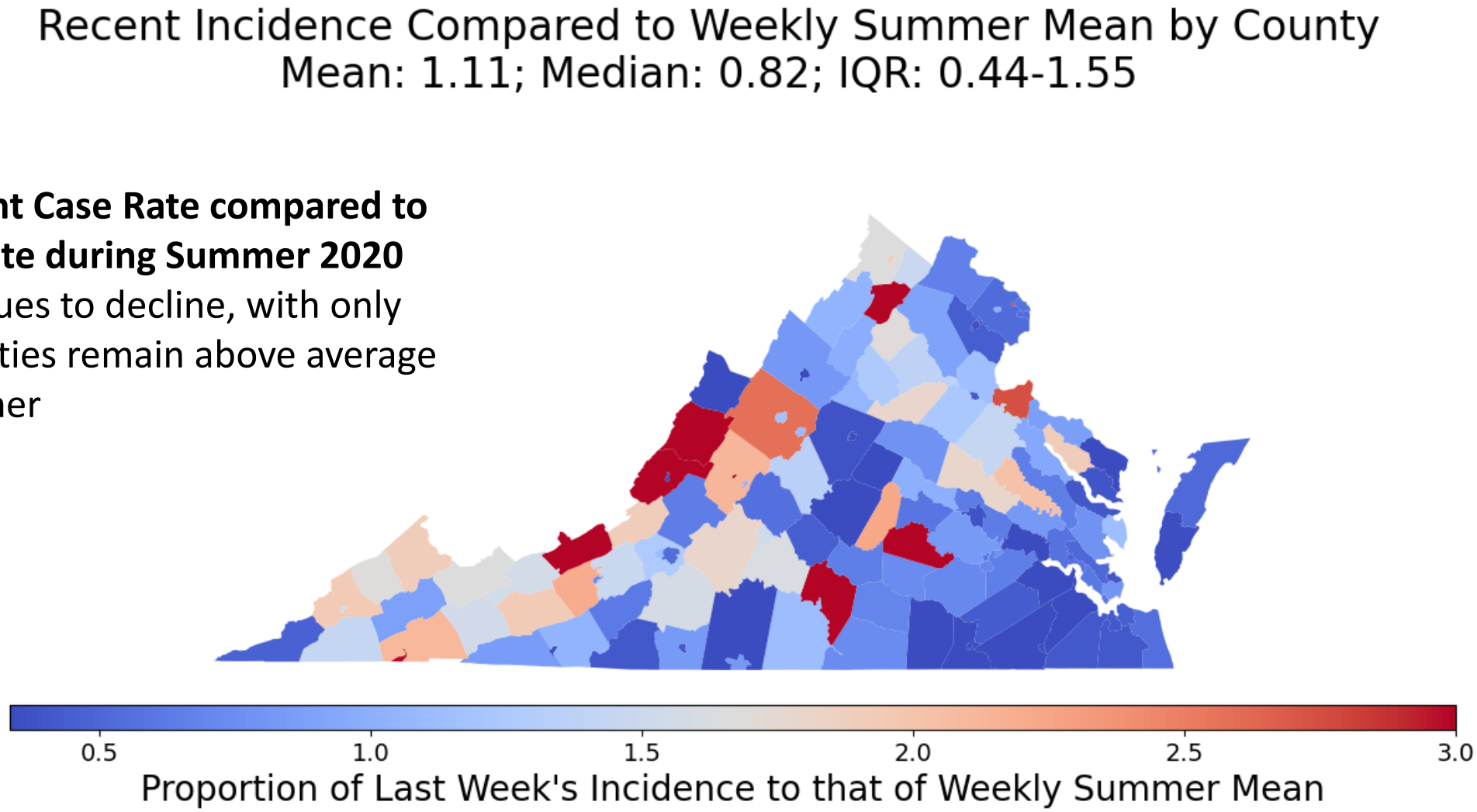
- Nearly all states are plateaued, several now in significant decline
- Some states in West are growing but may be leveling off

Virginia and her neighbors



- VA and neighbors remain in plateau, with declines increasing their pace
- Many neighbors are now below 10/100K level

Recent Incidence Compared to Summer 2020

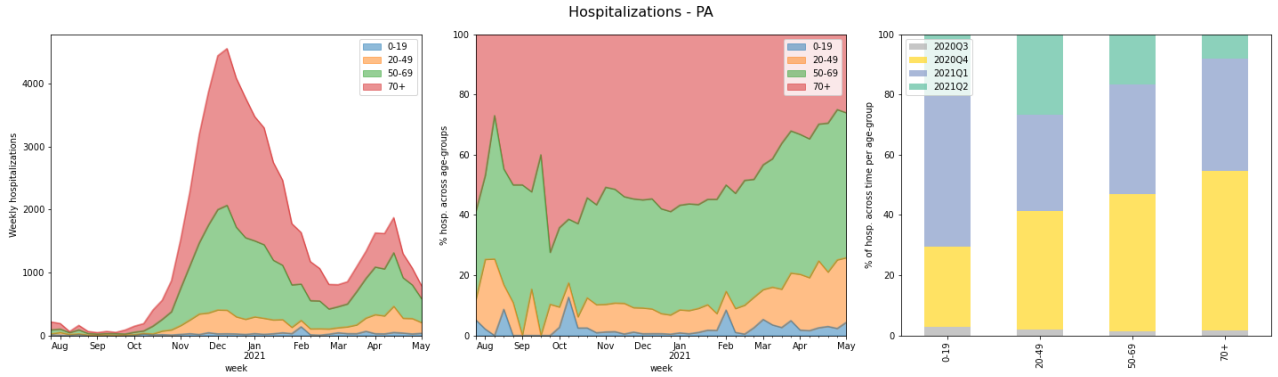


Ratio of Recent Case Rate compared to mean Case Rate during Summer 2020

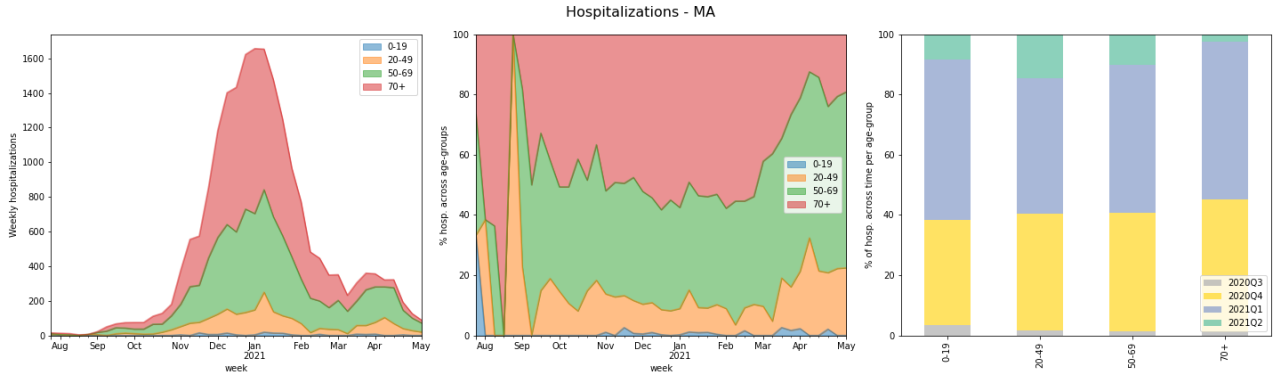
- Ratio continues to decline, with only 41% of counties remain above average of last summer

Shifting Age-Distributions - Hospitalizations

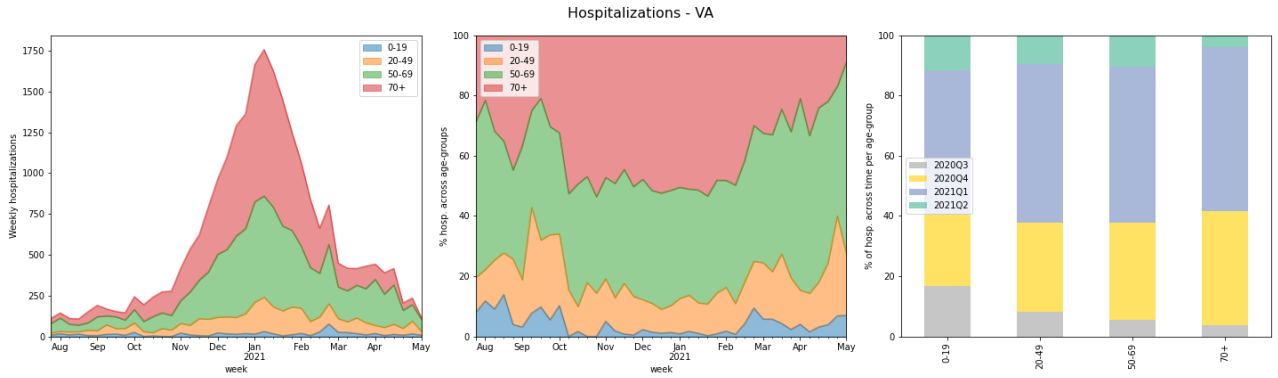
Pennsylvania



Massachusetts



Virginia



Shifting Age Distribution of cases being hospitalized

- Dual forces of vaccinations in older groups and severity of B.1.1.7 are shifting the age distribution of hospitalized patients
- Pennsylvania continues to make progress shrinking the share of 70+ hospitalized
- Massachusetts, with high levels of vaccinations, has almost eliminated hospitalizations, and the share of 70+ has stalled but at very low levels
- Virginia has made significant progress against 70+ hospitalizations and driven its rates down significantly, while others, like 0-19 and 20-49 continue to grow

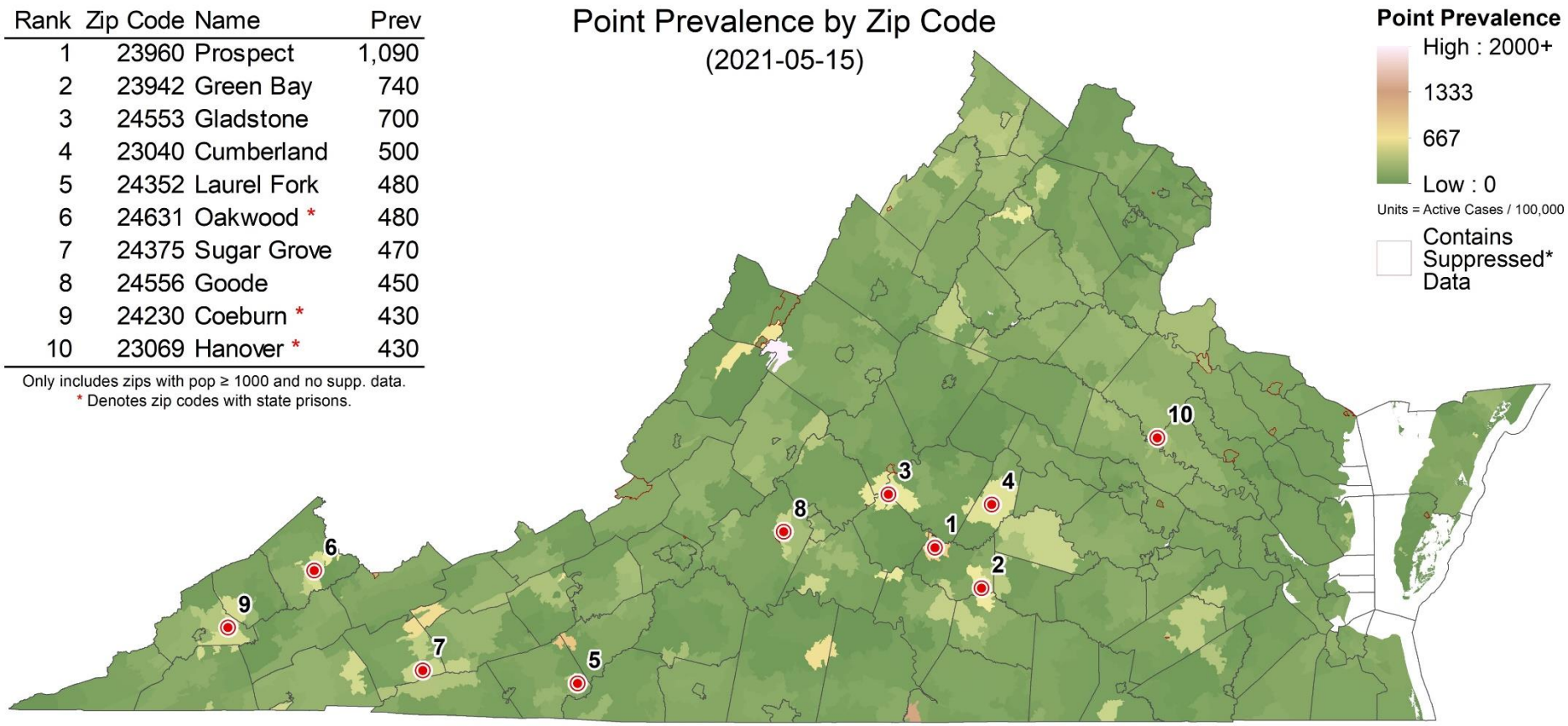
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Concentrations in Southwest, which was preceded by cluster of increased HCW rates last week
- Still some universities in top 10
- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prev
1	23960	Prospect	1,090
2	23942	Green Bay	740
3	24553	Gladstone	700
4	23040	Cumberland	500
5	24352	Laurel Fork	480
6	24631	Oakwood *	480
7	24375	Sugar Grove	470
8	24556	Goode	450
9	24230	Coeburn *	430
10	23069	Hanover *	430

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.



Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-05-15.

UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

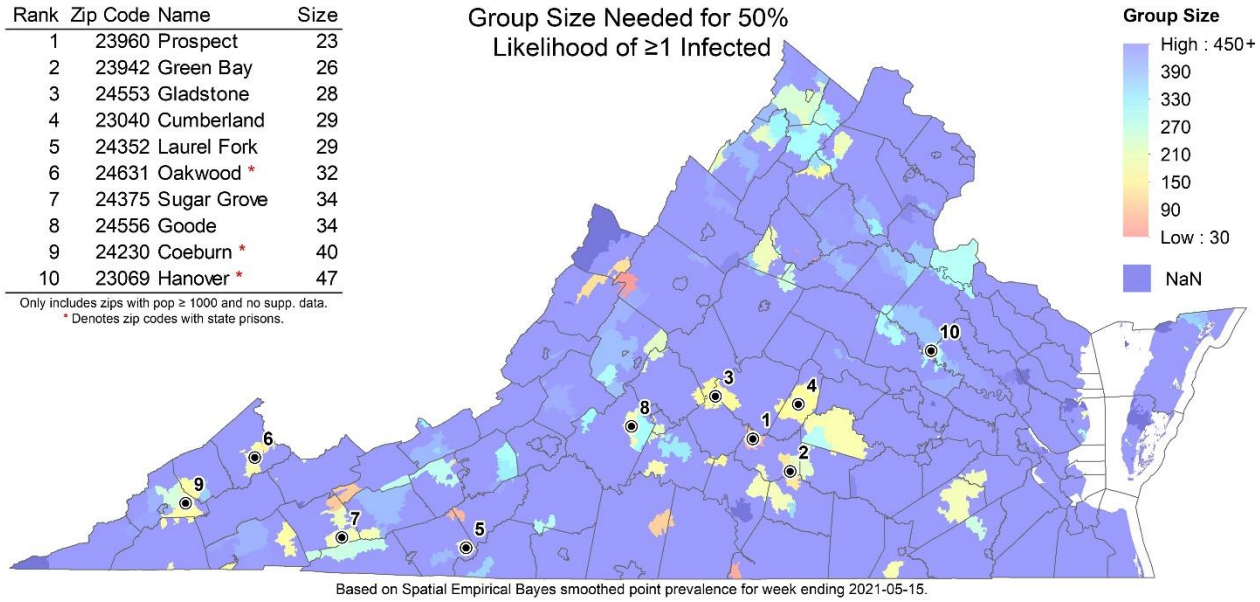
Risk of Exposure by Group Size and HCW prevalence

Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

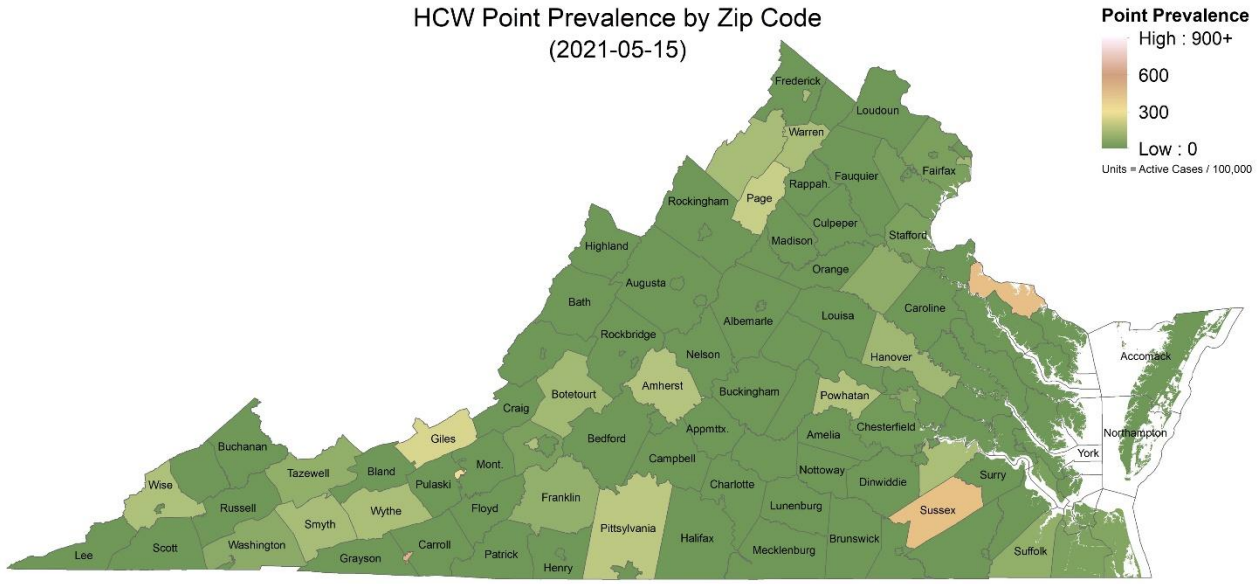
- **Group Size**: Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (eg in a group of 23 in Prospect, there is a 50% chance someone will be infected)
- **HCW prevalence**: Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator

Rank	Zip Code	Name	Size
1	23960	Prospect	23
2	23942	Green Bay	26
3	24553	Gladstone	28
4	23040	Cumberland	29
5	24352	Laurel Fork	29
6	24631	Oakwood *	32
7	24375	Sugar Grove	34
8	24556	Goode	34
9	24230	Coeburn *	40
10	23069	Hanover *	47

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.



Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-05-15.



Note: Scale differs from general public prevalence maps.

Current Hot-Spots

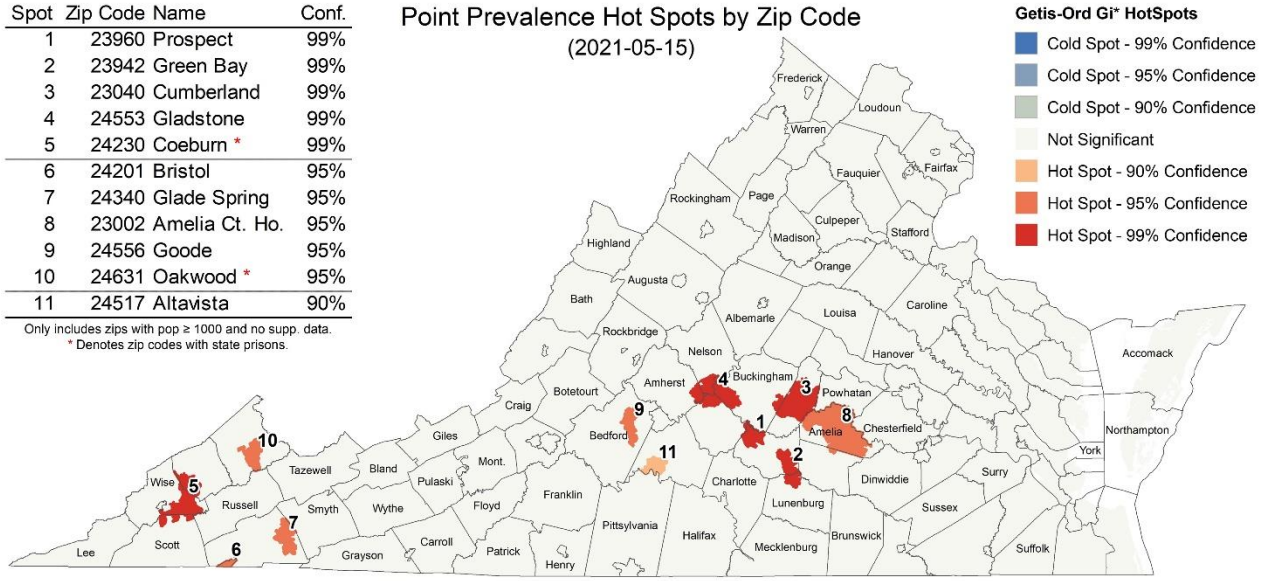
Case rates that are significantly different from neighboring areas or model projections

- **Spatial**: SaTScan based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations
- **Temporal**: The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model's projections

Spatial Hotspots

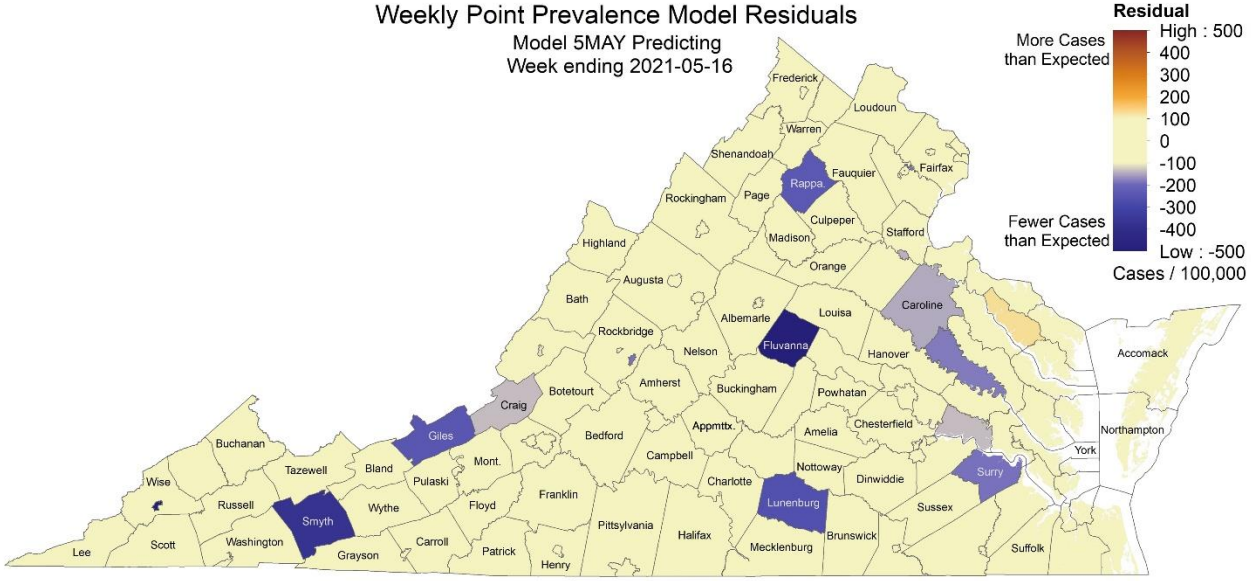
Spot	Zip Code	Name	Conf.
1	23960	Prospect	99%
2	23942	Green Bay	99%
3	23040	Cumberland	99%
4	24553	Gladstone	99%
5	24230	Coeburn *	99%
6	24201	Bristol	95%
7	24340	Glade Spring	95%
8	23002	Amelia Ct. Ho.	95%
9	24556	Goode	95%
10	24631	Oakwood *	95%
11	24517	Altavista	90%

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.



Based on Global Empirical Bayes smoothed point prevalence for week ending 2021-05-15.

Temporal Hotspots

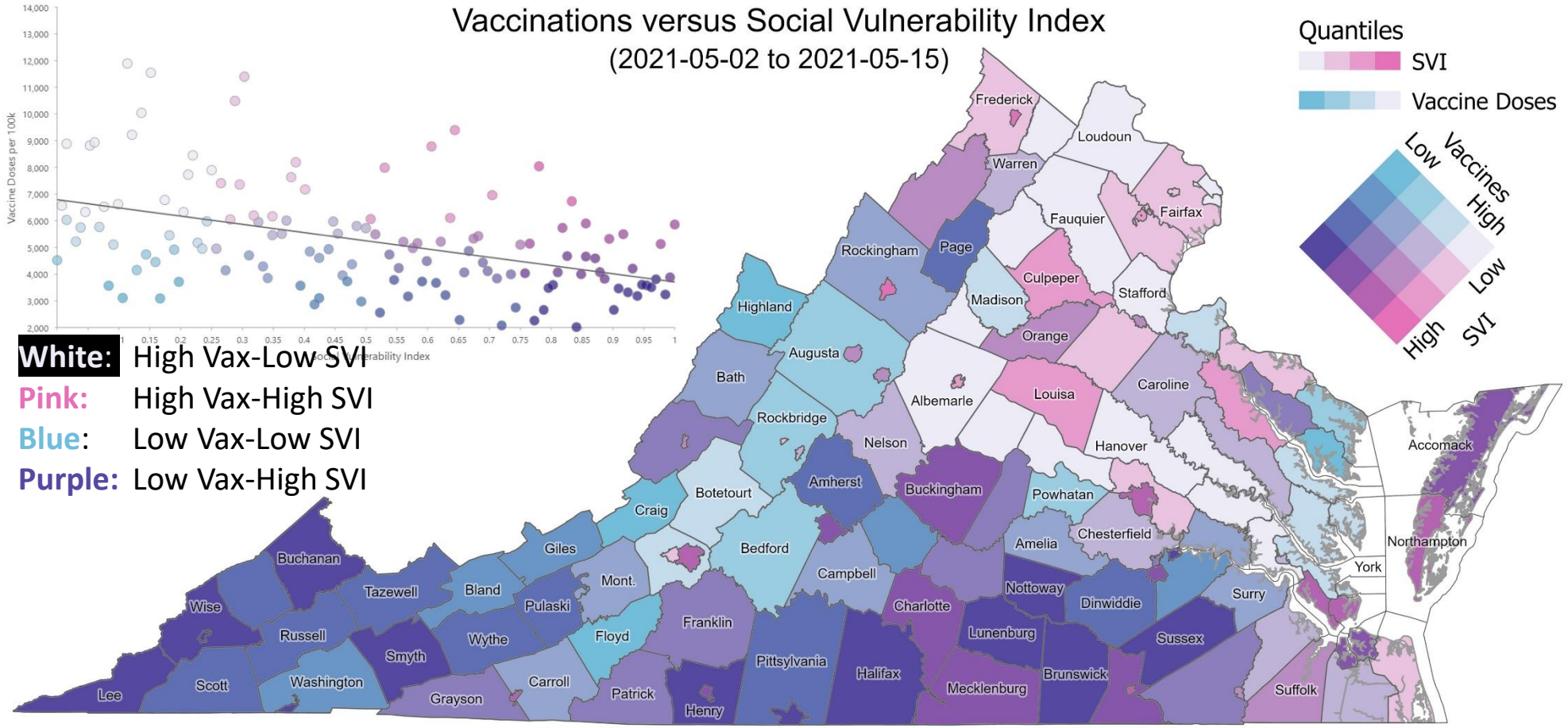


Moran's I = 0.005149, Z-Score = 0.466905, P-Value = 0.640568
No Residual Autocorrelation Detected

Social Vulnerability and Recent Vaccination Rates

Comparison of social vulnerability and vaccination rate in last 2 weeks by county

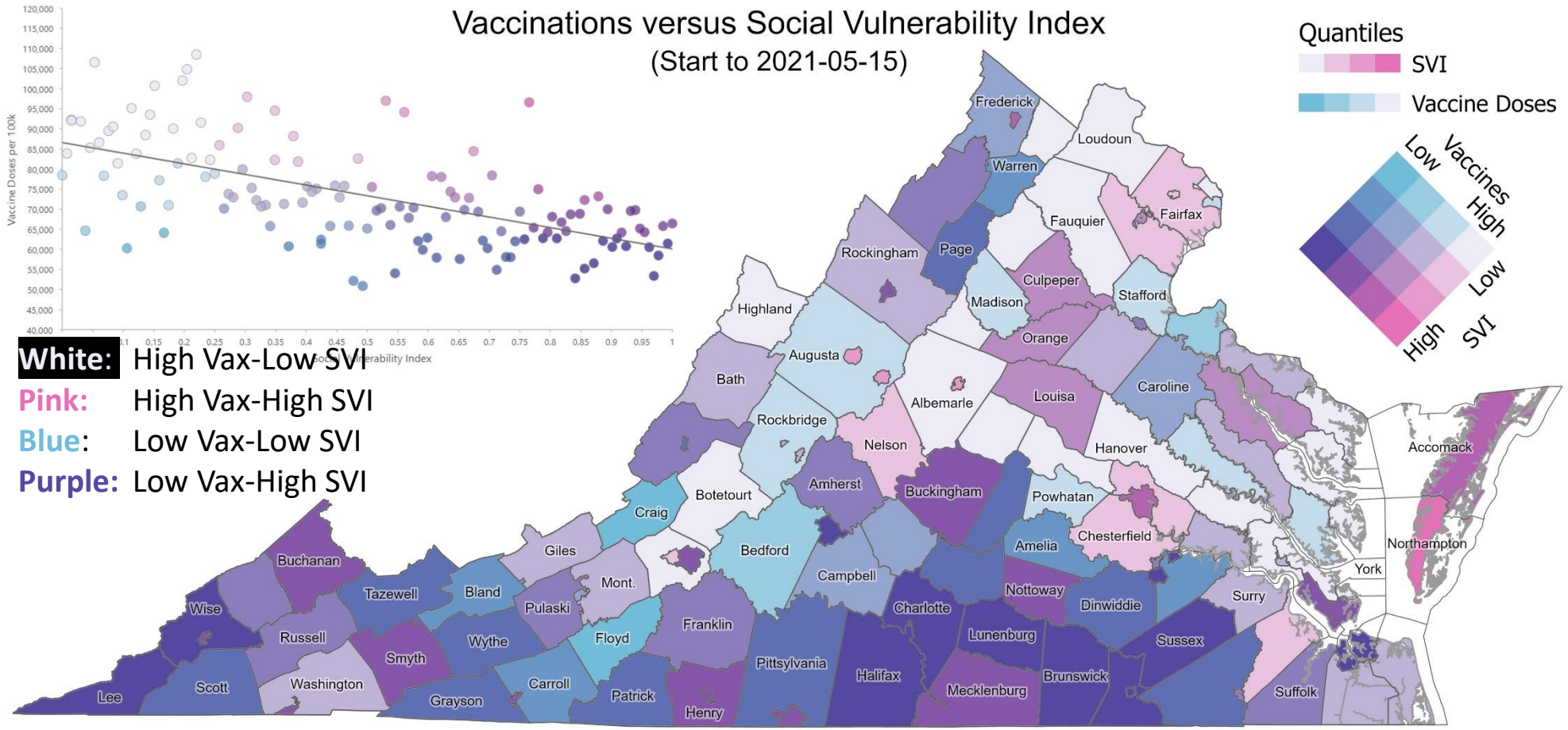
- **Social Vulnerability:** Each county's Social Vulnerability Index (CDC) compared with the level of vaccination



Social Vulnerability and Total Vaccination Rates

Comparison of social vulnerability and total vaccination rate since the start of vaccination

- **Social Vulnerability:** Each county's Social Vulnerability Index (CDC) compared with the level of vaccination



Model Update – Adaptive Fitting

Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

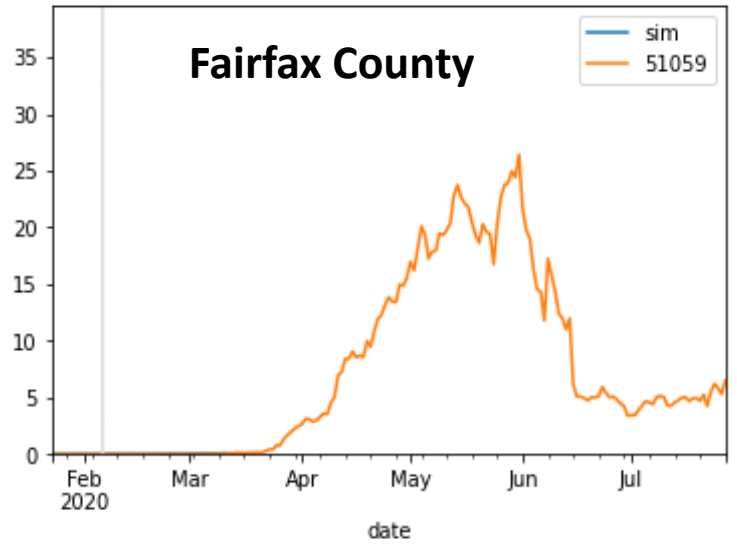
- Allows history to be precisely captured, and used to guide bounds on projections

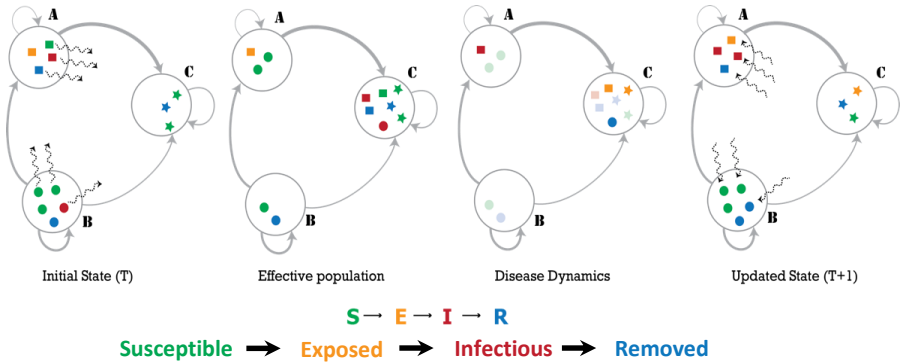
Model: An alternative use of the same meta-population model, PatchSim

- Allows for future "what-if" Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding





UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

Using Ensemble Model to Guide Projections

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

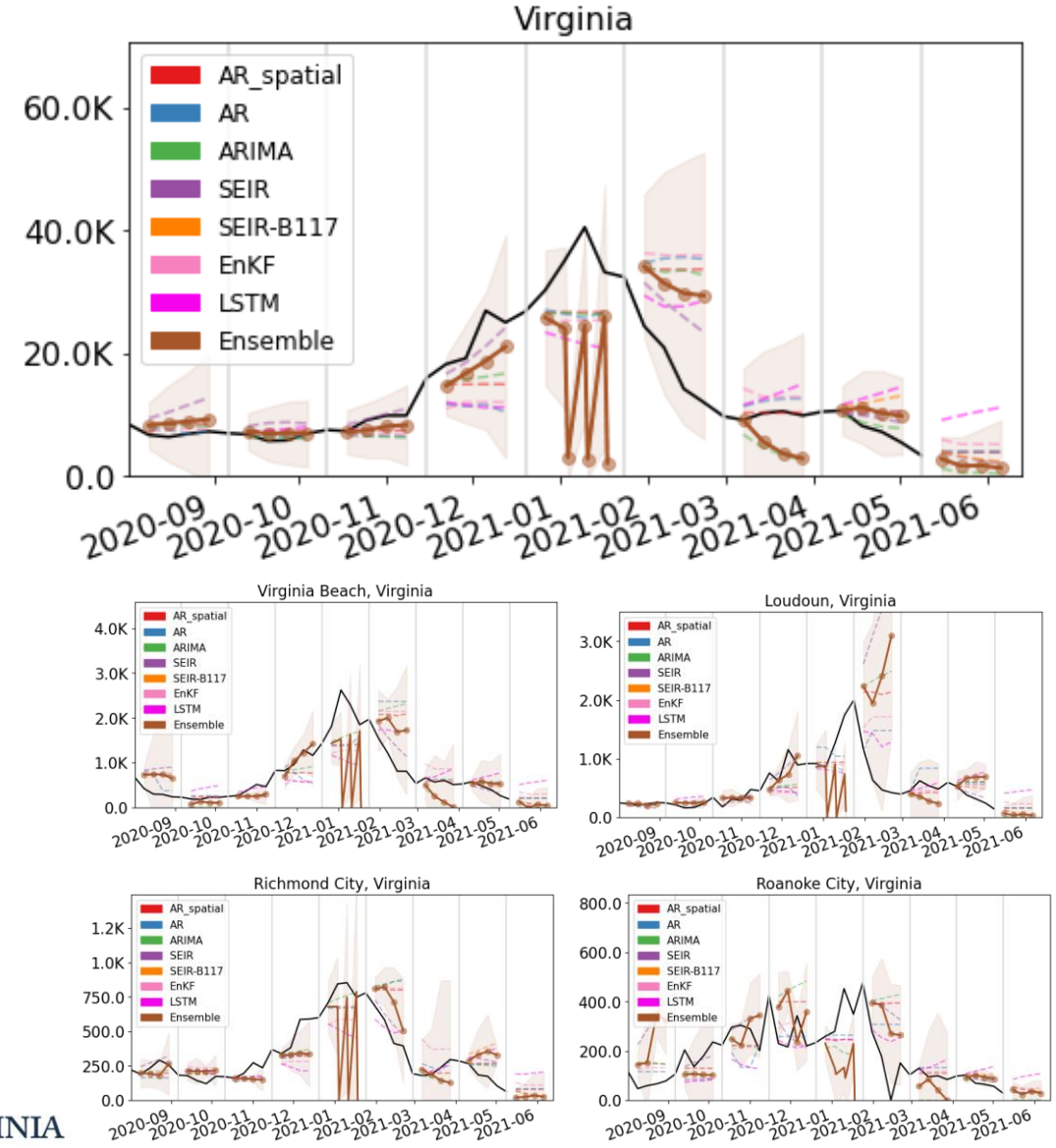
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

<u>Weekly forecasts</u> done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional ‘surveillance’ for making scenario-based projections.

Also submitted to CDC Forecast Hub.



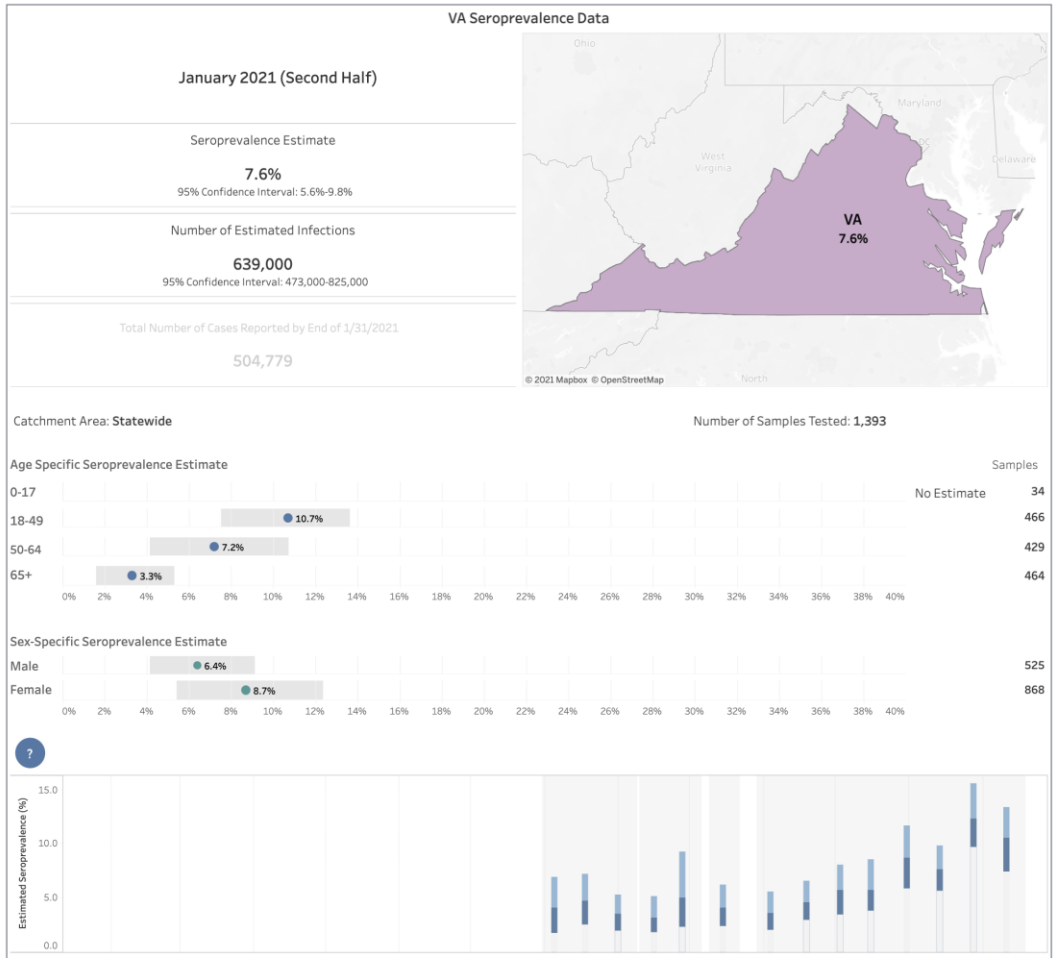
Seroprevalence updates to model design

Several seroprevalence studies provide better picture of how many actual infections have occurred

- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 7.6% [5.6% – 9.8%] seroprevalence as of Jan 7th – 21st up from 5.7% a month earlier

These findings are equivalent to an ascertainment ratio of ~2x in the future, with bounds of (1.3x to 3x)

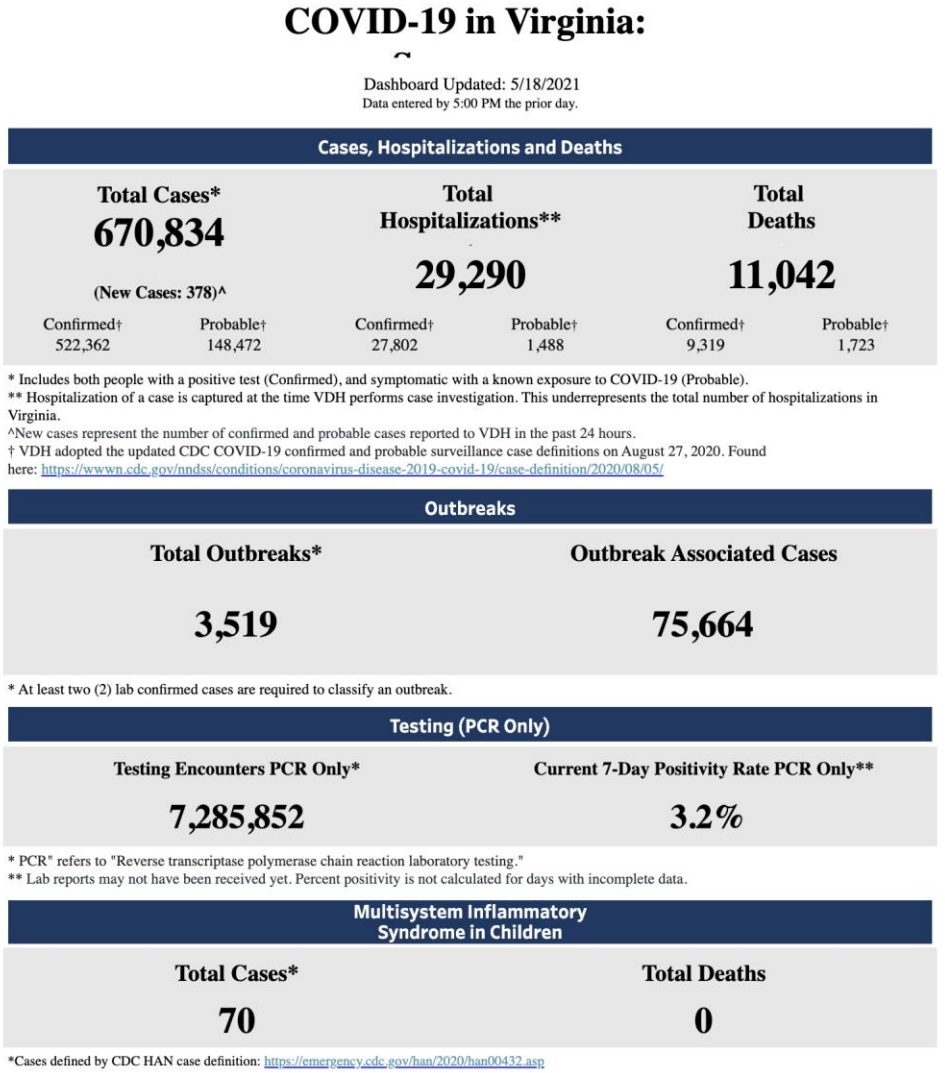
- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being used)



https://covid.cdc.gov/covid-data-tracker/#national-lab

Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data and ensemble's forecast
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (1x to 7x) guided by seroprevalence studies
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes generated using the collection of fit models run into the future
  - **Mean trend from last 7 days of observed cases and first week of ensemble's forecast used**
  - Outliers removed based on variances in the previous 3 weeks
  - 2 week interpolation to smooth transitions in rapidly changing trajectories



COVID-19 in Virginia:

Dashboard Updated: 5/18/2021
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths

Total Cases*		Total Hospitalizations**		Total Deaths	
670,834		29,290		11,042	
(New Cases: 378)^					
Confirmed†	Probable†	Confirmed†	Probable†	Confirmed†	Probable†
522,362	148,472	27,802	1,488	9,319	1,723

* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).
** Hospitalization of a case is captured at the time VDH performs case investigation. This underrepresents the total number of hospitalizations in Virginia.
^New cases represent the number of confirmed and probable cases reported to VDH in the past 24 hours.
† VDH adopted the updated CDC COVID-19 confirmed and probable surveillance case definitions on August 27, 2020. Found here: https://wwwn.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/08/05/

Outbreaks

Total Outbreaks*	Outbreak Associated Cases
3,519	75,664

* At least two (2) lab confirmed cases are required to classify an outbreak.

Testing (PCR Only)

Testing Encounters PCR Only*	Current 7-Day Positivity Rate PCR Only**
7,285,852	3.2%

* PCR" refers to "Reverse transcriptase polymerase chain reaction laboratory testing."
** Lab reports may not have been received yet. Percent positivity is not calculated for days with incomplete data.

Multisystem Inflammatory Syndrome in Children

Total Cases*	Total Deaths
70	0

*Cases defined by CDC HAN case definition: https://emergency.cdc.gov/han/2020/han00432.asp

Accessed 9:00am May 19, 2021

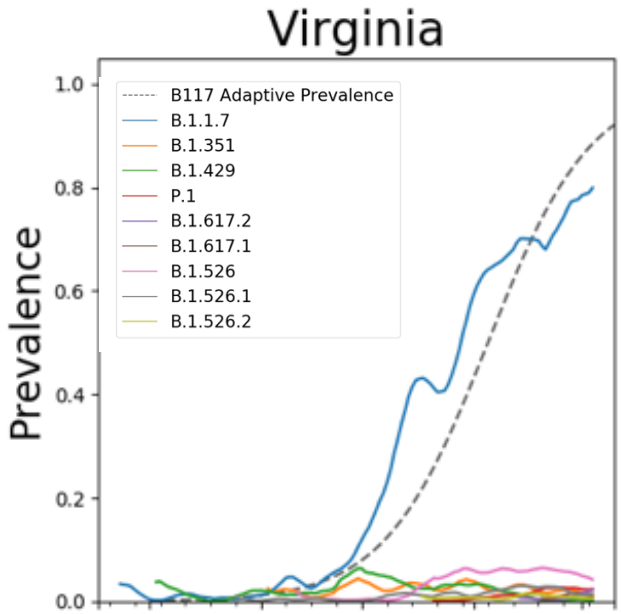
https://www.vdh.virginia.gov/coronavirus/

Scenarios – Transmission Conditions

- Variety of factors continue to drive transmission rates
  - Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices
- Plausible levels of transmission can be bounded by past experience
  - Assess transmission levels at the county level from May 1, 2020 – Sept 1, 2020 or current, whichever is highest
- Projection Scenario:
  - **Adaptive:** Control remains as is currently experienced into the future
  - **Fatigued Control**:
    - Highest level of transmission (95th percentile) increased by additional 5%
    - Transition to this level over 4 weeks, remain at this level for the summer, then return to Adaptive

Scenarios – Mixed Variants Condition

- Variant B.1.1.7 has reached dominance in Virginia but no longer is growing at a predictable pace as variants compete
- Other variants with differing levels of transmissibility, immune escape, and impacts on severity also exist, to varying degrees
- Transmissibility boosting effects and growth of variants are no longer predictable
  - Rely on adaptive fitting to find transmissibility trends for projection
- Immune Escape
  - Many variants demonstrate the ability to evade immunity, both natural and vaccine-induced, uncertainty remains high thus this is not factored into the model
- Impact on Severity
  - Assume current variant prevalence remain relatively stable into future
  - Severity increases:
    - B.1.1.7= 1.6 times hospitalization and death
    - P.1 = 1.5 times hospitalization and death
    - B.1.351 = 1.5 times hospitalization and death



outbreak.info

GISAID

Outbreak Info

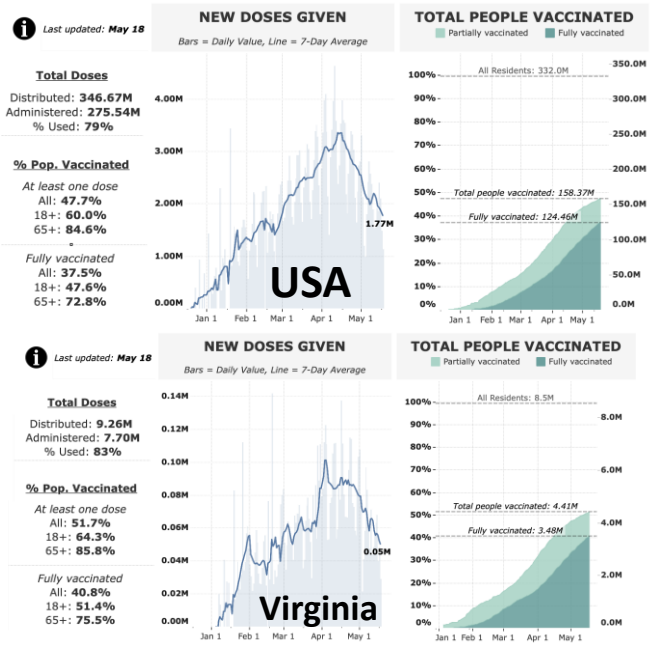
Scenarios – Vaccination Conditions

Assumed vaccine efficacies

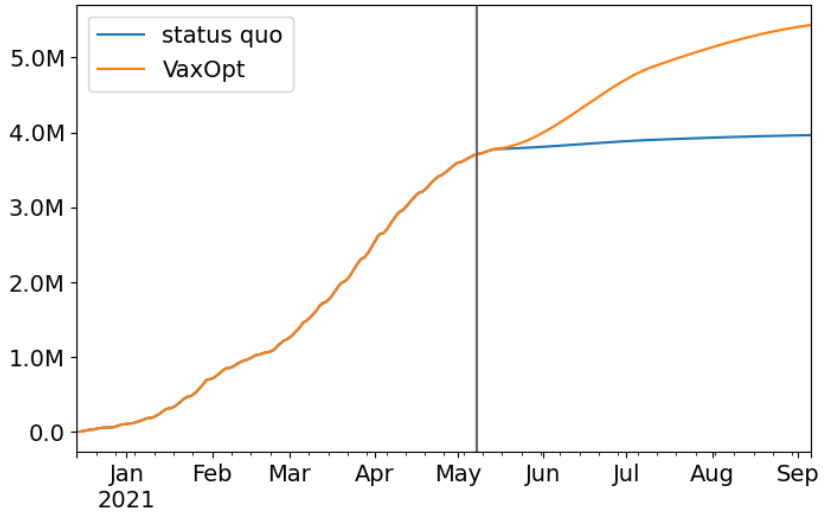
- **Pfizer/Moderna**: 50% after first dose, 95% after second dose (3.5 week gap)
- **J & J** : 67% efficacy after first (and only) dose
- Delay to efficacy from doses is 14 days, immunity lasts at least 7m (NEJM study)

Two Vaccine Administration Scenarios

- Acceptance at county level = regional acceptance +/- relative current vax
- **Status quo (no label):** Slowly reach COVIDcast estimated acceptance level [statewide 55%] by end of Summer (Labor Day)
- **Optimistic (VaxOpt):** Expand acceptance to 75% by Labor day [66.7% by July 4th]



Source: https://ckelly17.github.io/vaccine_dashboard.html



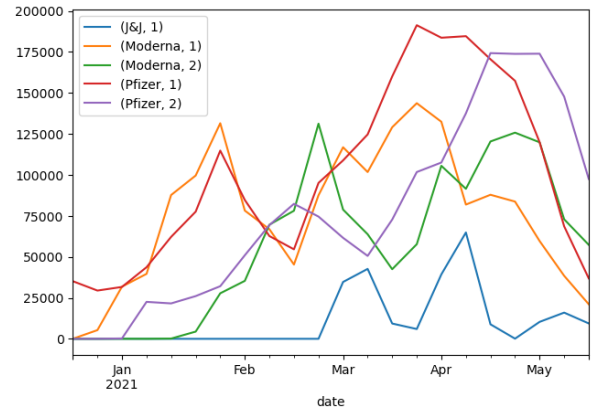
Monthly first doses

Date	status quo	VaxOpt
2020-12-31	99.4K	99.4K
2021-01-31	599.4K	599.4K
2021-02-28	532.8K	532.8K
2021-03-31	1.3M	1.3M
2021-04-30	1.1M	1.1M
2021-05-31	231.3K	406.4K
2021-06-30	75.2K	708.9K
2021-07-31	47.7K	436.7K
2021-08-31	30.8K	276.3K
2021-09-30	3.8K	33.2K

Cumulative

Date	status quo	VaxOpt
2020-12-31	99.4K	99.4K
2021-01-31	698.8K	698.8K
2021-02-28	1.2M	1.2M
2021-03-31	2.5M	2.5M
2021-04-30	3.6M	3.6M
2021-05-31	3.8M	4.0M
2021-06-30	3.9M	4.7M
2021-07-31	3.9M	5.1M
2021-08-31	4.0M	5.4M
2021-09-30	4.0M	5.4M

Weekly VA doses administered by manufacturer



UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE

Scenarios – Combined Conditions

Name	Txm Controls	Variant Boosting	Vax	Description
Adaptive	C	Mixed	SQ	Likely trajectory based on conditions remaining similar to how they are now
Adaptive-FatigueControl	F	Mixed	SQ	Worst case trajectory if control conditions deteriorate to highest transmission rates of the past
Adaptive-VaxOpt	C	Mixed	VO	Likely trajectory based on conditions remaining similar to now, but with improvements to vaccine acceptance
Adaptive-FatigueControl-VaxOpt	F	Mixed	VO	Worst case trajectory if control conditions deteriorate to worst of the past, with improvements to vax acceptance

Transmission Controls: C = Current levels persist into the future
F = Fatiguing controls drift to worst levels of last summer and persist

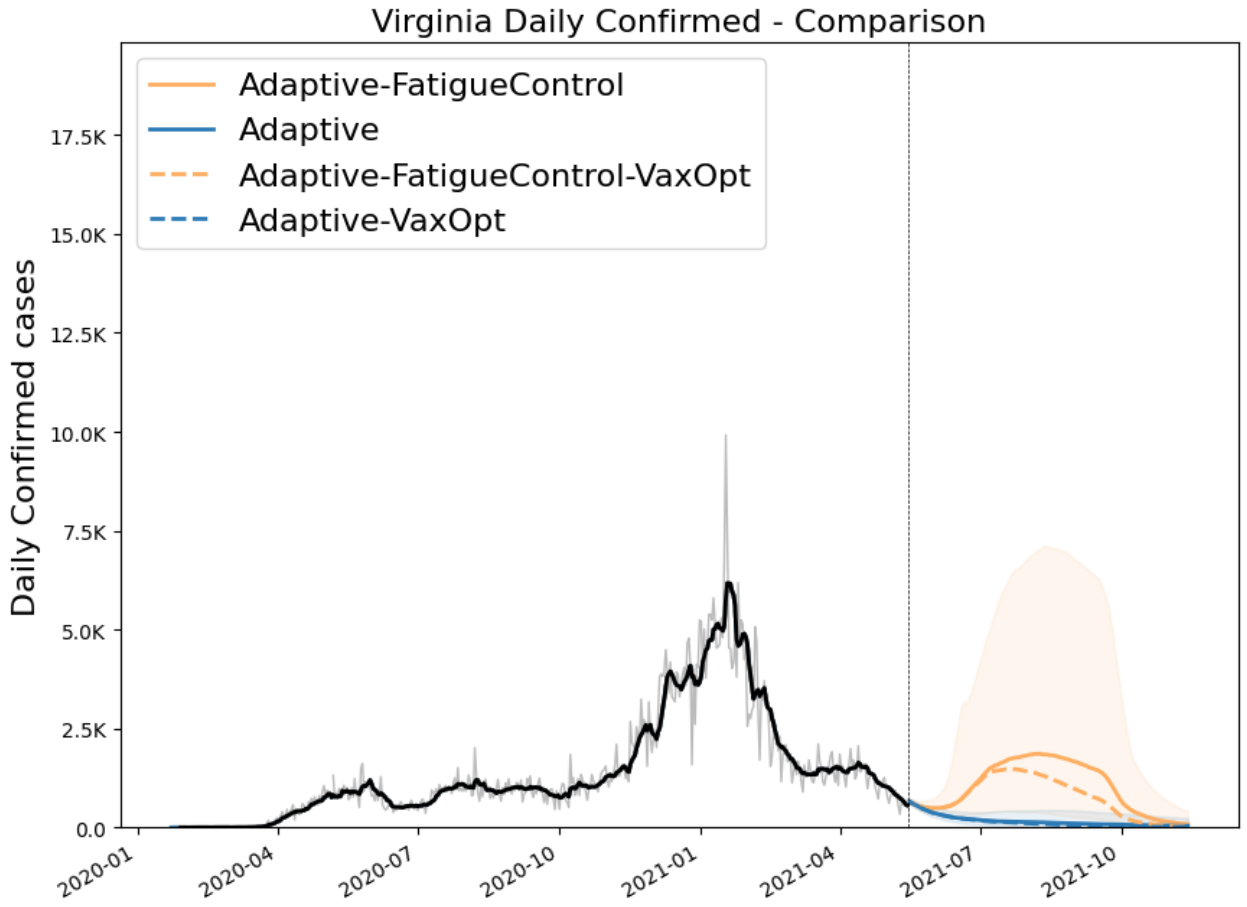
Variant Boosting: Mixed = Variety of variants, no future txm boosting, but with severity impacts from current levels

Vaccinations: SQ = Status quo acceptance leads to low rates of vaccination through the summer
VO = Vaccination acceptance optimistically expands with increased rates through the summer

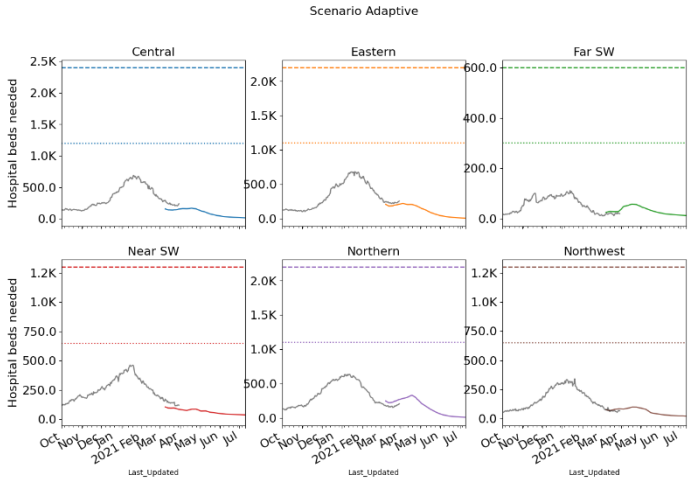
Model Results

Outcome Projections

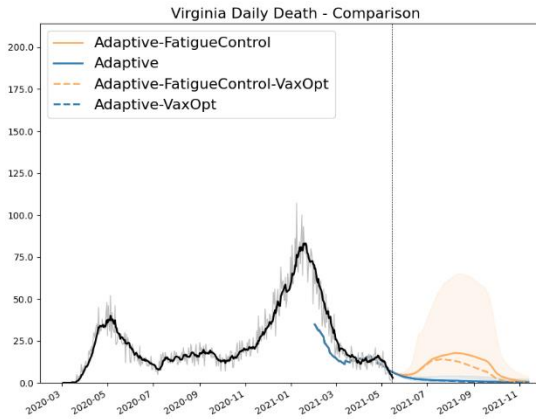
Confirmed cases



Estimated Hospital Occupancy

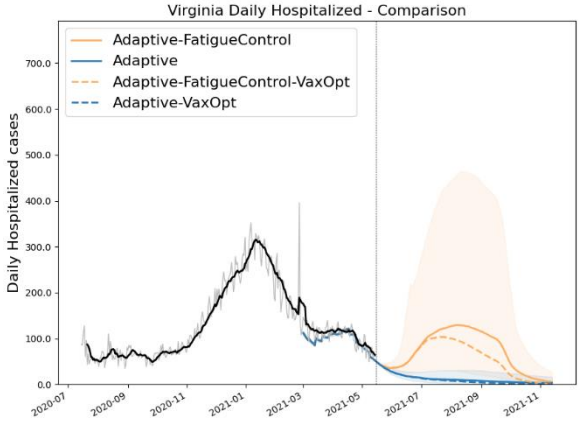


Daily Deaths



Death ground truth from VDH "Event Date" data, most recent dates are not complete

Daily Hospitalized

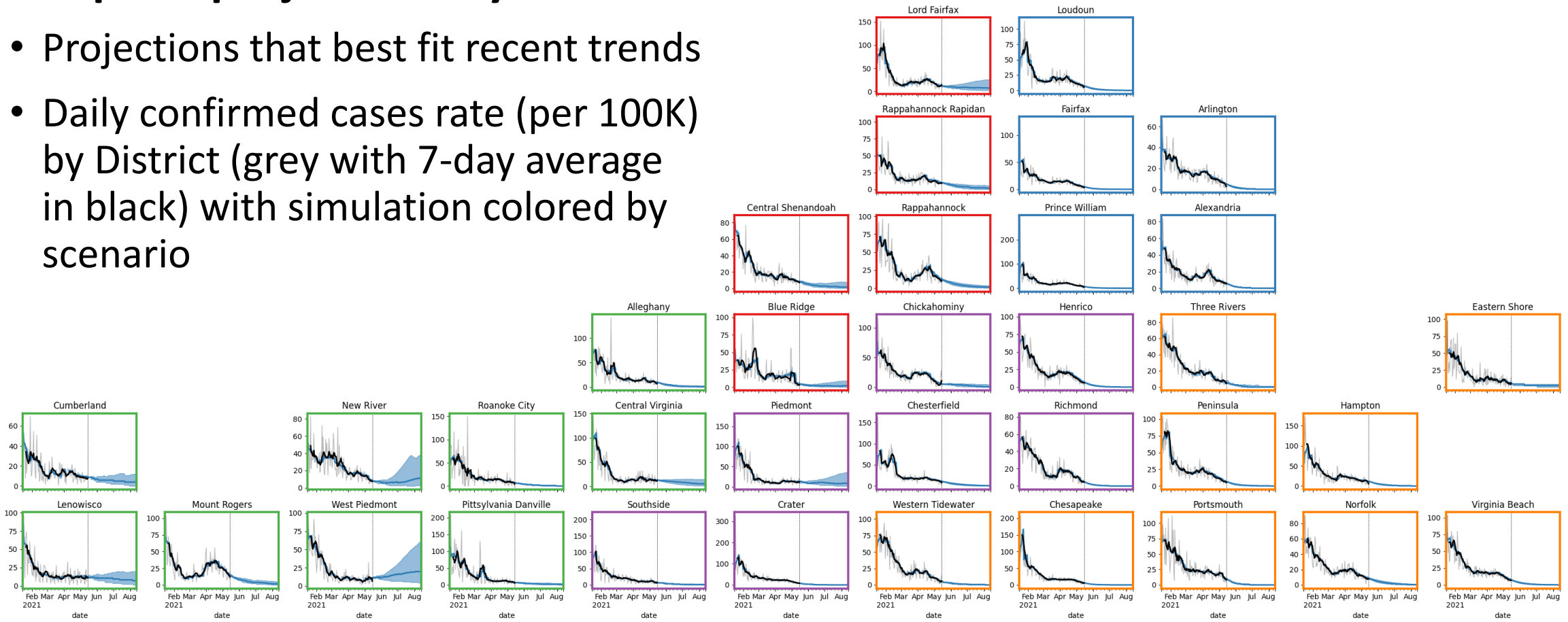


UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

District Level Projections: Adaptive

Adaptive projections by District

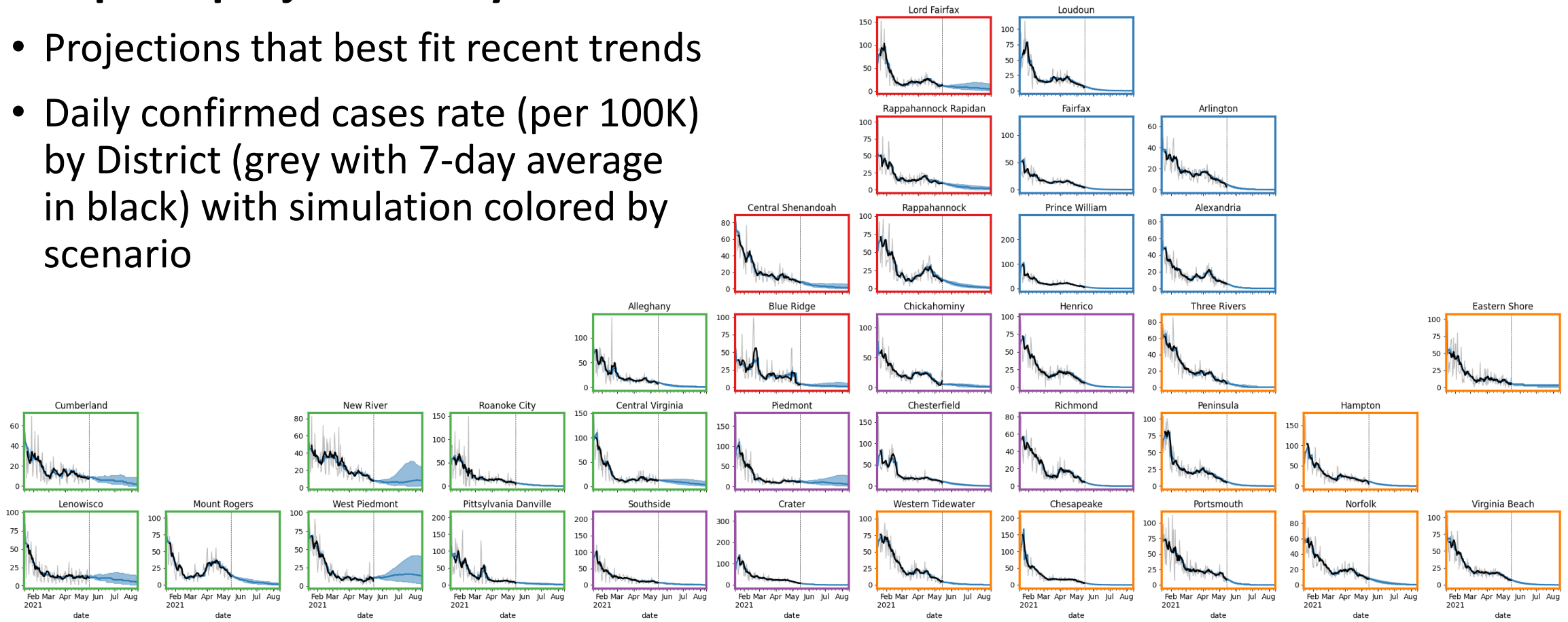
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario



District Level Projections: Adaptive-VaxOpt

Adaptive projections by District

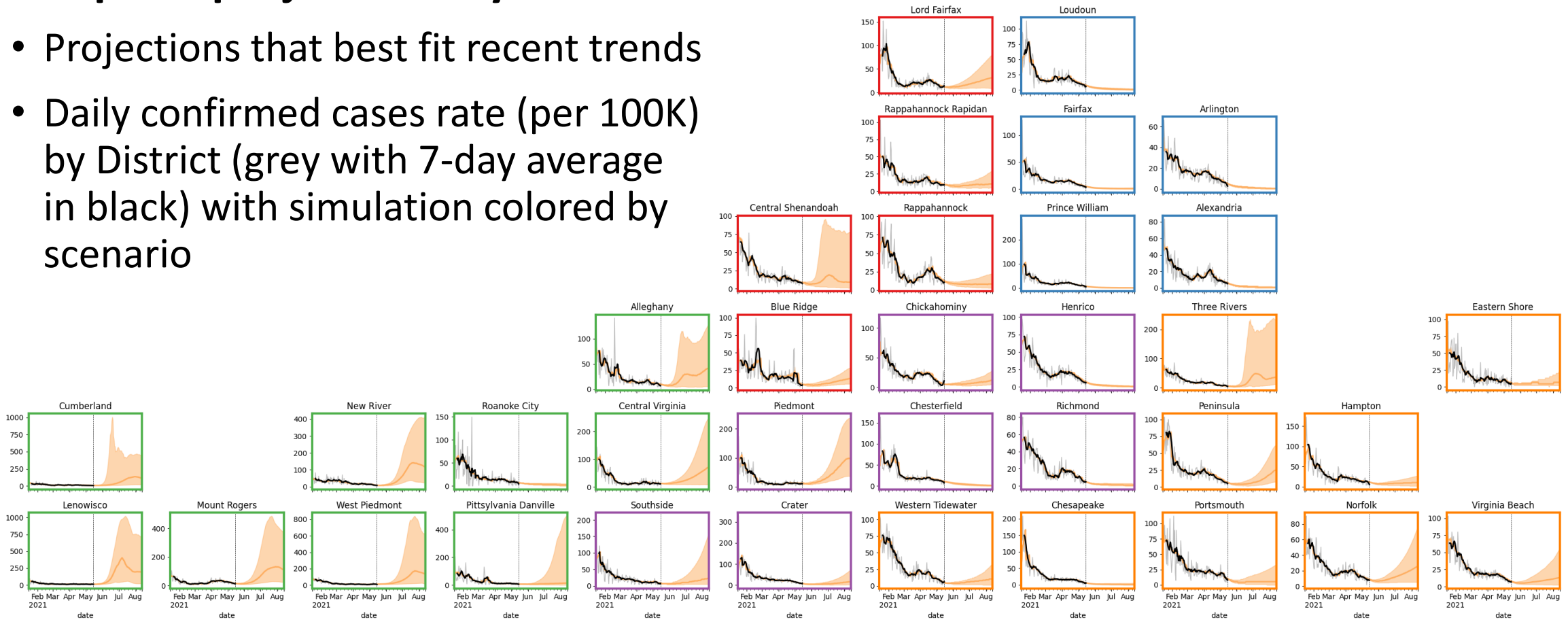
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario



District Level Projections: Adaptive-FatigueControl

Adaptive projections by District

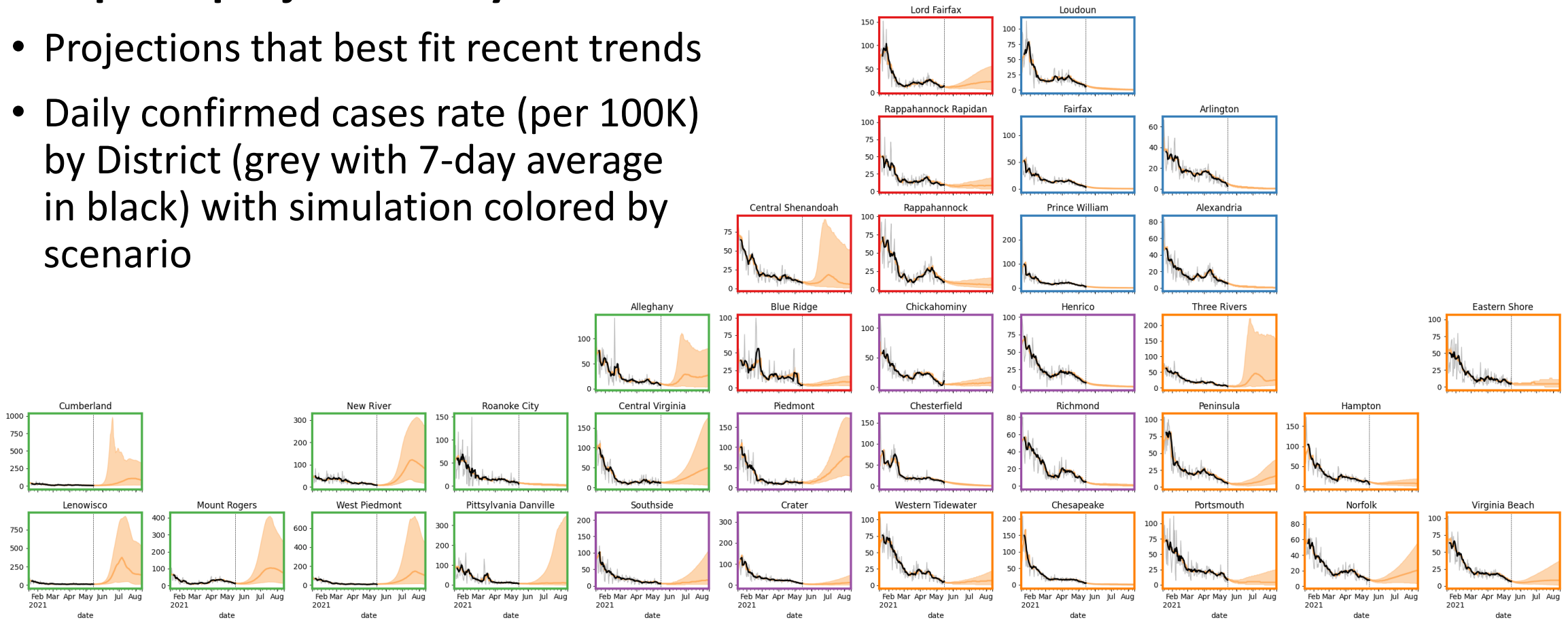
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario



District Level Projections: Adaptive-FatigueControl-VaxOpt

Adaptive projections by District

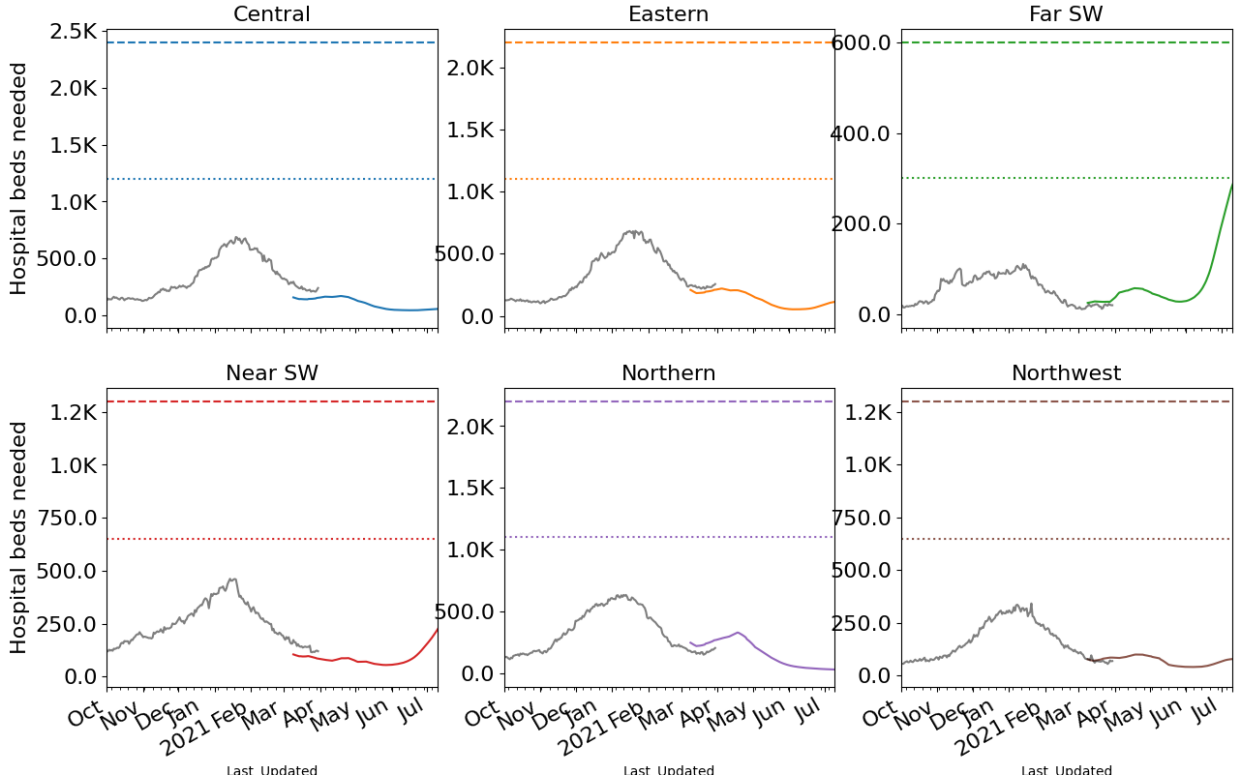
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

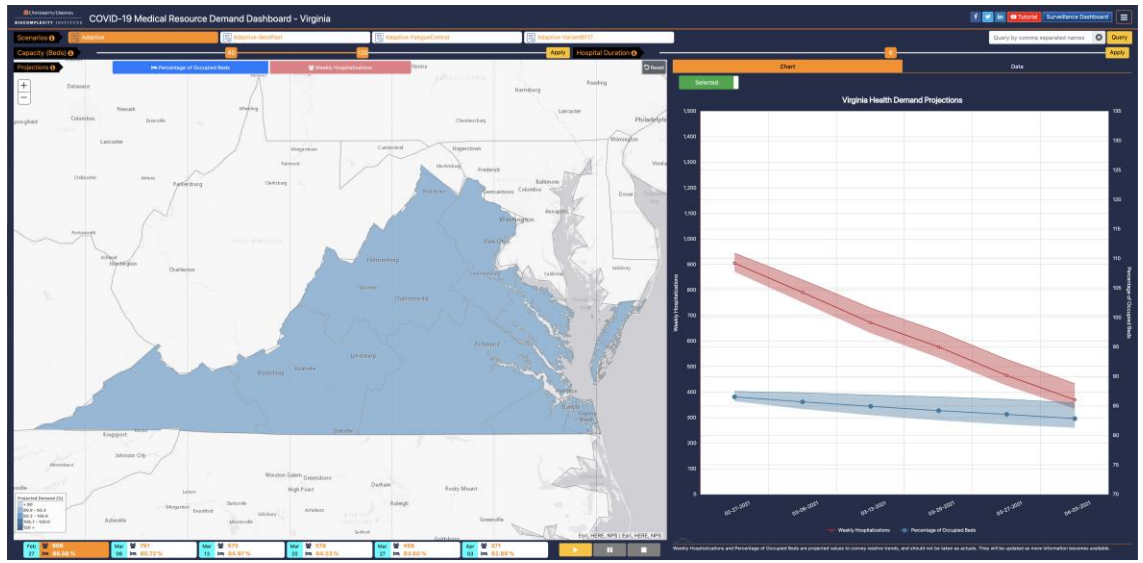


Hospital Demand and Bed Capacity by Region

Capacities* by Region – Adaptive-FatigueControl-DominantB117

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds





https://nssac.bii.virginia.edu/covid-19/vmrddash/

If Adaptive-FatigueControl-DominantB117 scenario persists:

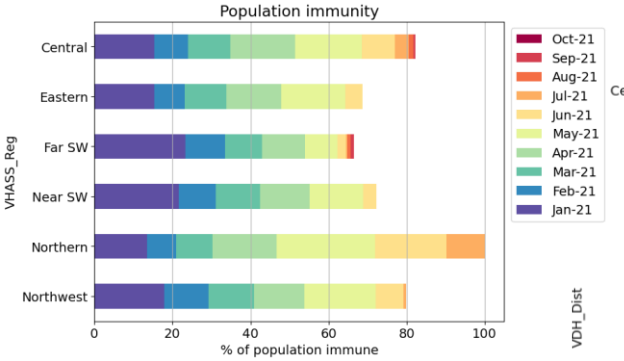
- No capacity challenges for hospital beds in near-term

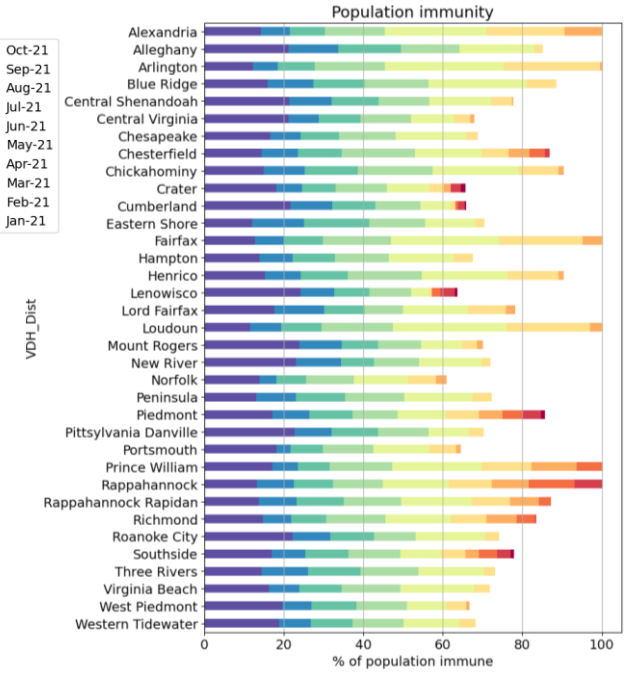
* Assumes average length of stay of 8 days

Virginia's Progress on Population Immunity

Natural Immunity and Vaccines combine to produce a population level of immunity

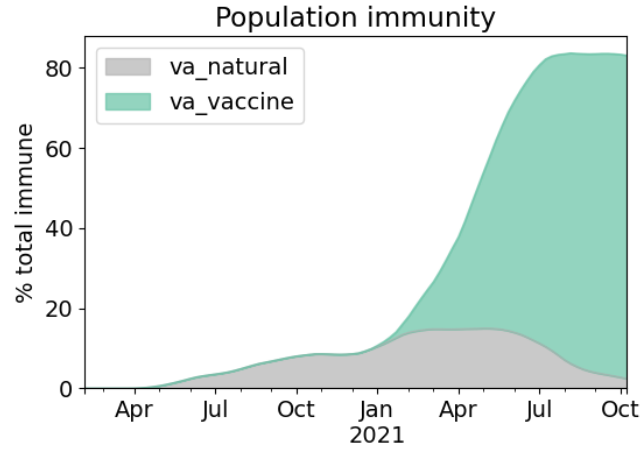
- Duration of immunity from infection with SARS-CoV2 still not well understood
  - We assume a conservative 6 month period of protection for these calculations
  - Natural immunity is well calibrated to recent seroprevalence surveys
- Vaccine induced immunity is likely to last longer, we assume indefinite protection
  - This also assumes that all administered vaccines remain protective against current and future novel variants
- Population immunity depends on a very high proportion of the population getting vaccinated
  - Using regional vaccine acceptance





Region	% immune (est.)*
Central	63%
Eastern	58%
Far SW	60%
Near SW	63%
Northern	62%
Northwest	65%
Virginia	**62%**

* As of May 9, 2021



UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

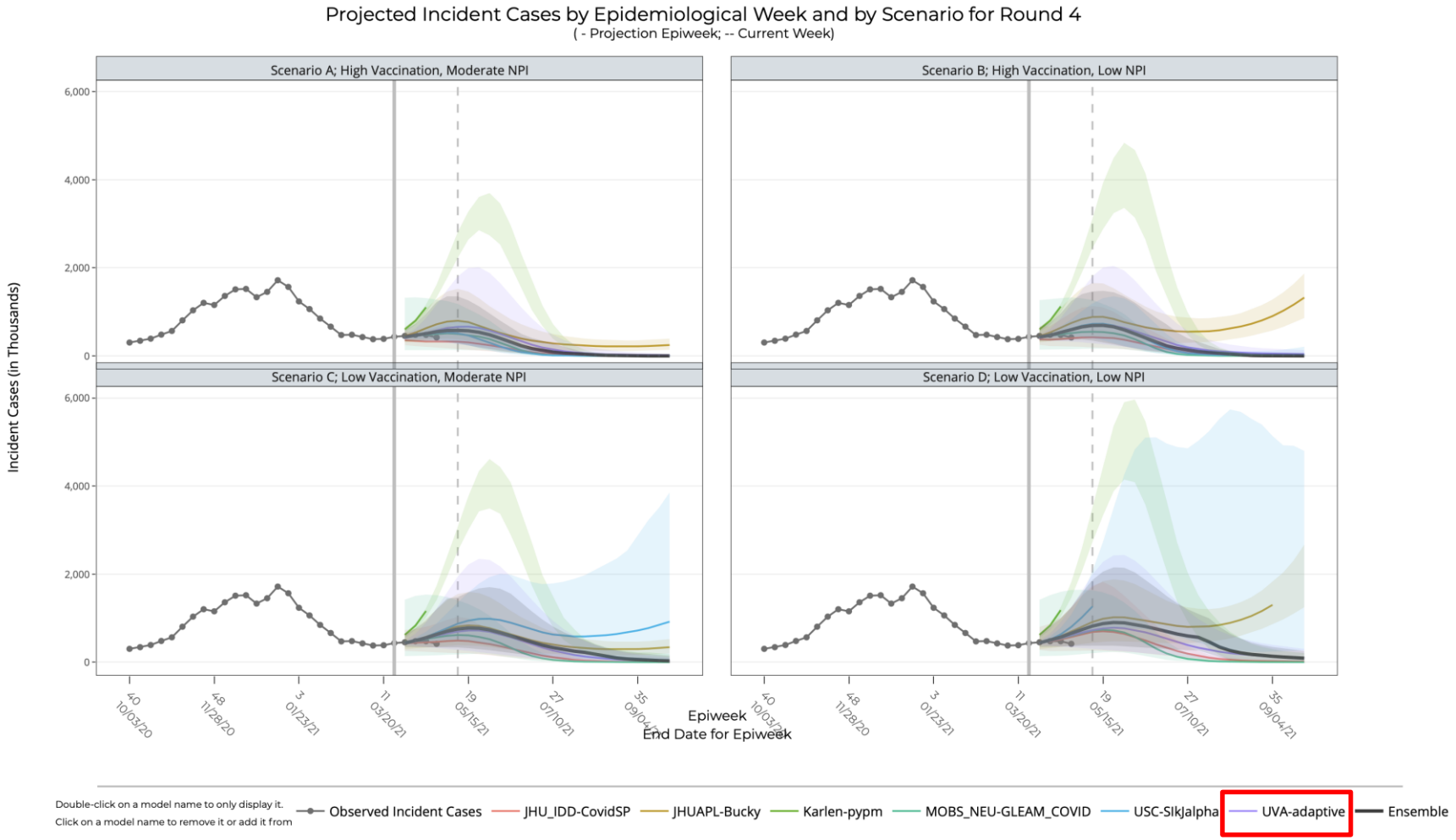
COVID-19 Scenario Modeling Hub

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios that vary vaccine rates (high – low) and levels of control (moderate and low)

Round 5 updates available this week

Published May 5th, 2021 in MMWR

https://covid19scenariomodelinghub.org/viz.html



Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

- **Case rates in Virginia continue to decline with pace accelerating in some districts**
- VA mean weekly incidence down to 6/100K from 8/100K, US down (10 from 12 per 100K)
- Vaccination rates have slowed considerably, but population immunity now estimated over 60%
- Projections show declining rate overall across Commonwealth
- Recent updates:
  - Minor updates to measured acceptance levels, validated with additional national survey
  - Added vaccination scenarios to compare status quo acceptance levels against expanded optimistic levels
- The situation continues to change. Models continue to be updated regularly.

References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS Computational Biology* 15.9 (2019): e1007111.

Arindam Fadikar, Dave Higdon, Jiangzhuo Chen, Bryan Lewis, Srinivasan Venkatramanan, and Madhav Marathe. Calibrating a stochastic, agent-based model using quantile-based emulation. SIAM/ASA Journal on Uncertainty Quantification, 6(4):1685–1706, 2018.

Adiga, Aniruddha, Srinivasan Venkatramanan, Akhil Peddireddy, et al. "Evaluating the impact of international airline suspensions on COVID-19 direct importation risk." *medRxiv* (2020)

NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. https://github.com/NSSAC/PatchSim

Virginia Department of Health. COVID-19 in Virginia. http://www.vdh.virginia.gov/coronavirus/

Biocomplexity Institute. COVID-19 Surveillance Dashboard. https://nssac.bii.virginia.edu/covid-19/dashboard/

Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/

Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

Points of Contact

Bryan Lewis
brylew@virginia.edu

Srini Venkatramanan
srini@virginia.edu

Madhav Marathe
marathe@virginia.edu

Chris Barrett
ChrisBarrett@virginia.edu

Biocomplexity COVID-19 Response Team

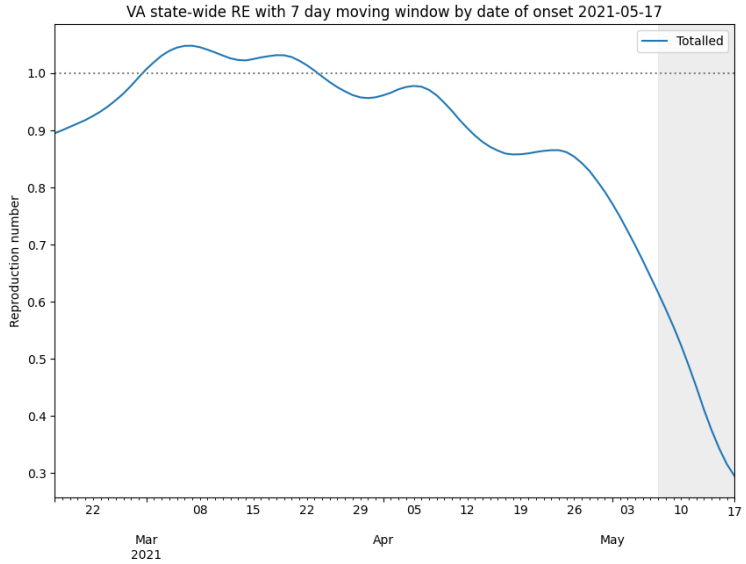
Aniruddha Adiga, Abhijin Adiga, Hannah Baek, Chris Barrett, Golda Barrow, Richard Beckman, Parantapa Bhattacharya, Jiangzhuo Chen, Clark Cucinell, Patrick Corbett, Allan Dickerman, Stephen Eubank, Stefan Hoops, Ben Hurt, Ron Kenyon, Brian Klahn, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, Madhav Marathe, Henning Mortveit, Mark Orr, Joseph Outten, Akhil Peddireddy, Przemyslaw Porebski, Erin Raymond, Jose Bayoan Santiago Calderon, James Schlitt, Samarth Swarup, Alex Telionis, Srinivasan Venkatramanan, Anil Vullikanti, James Walke, Andrew Warren, Amanda Wilson, Dawen Xie

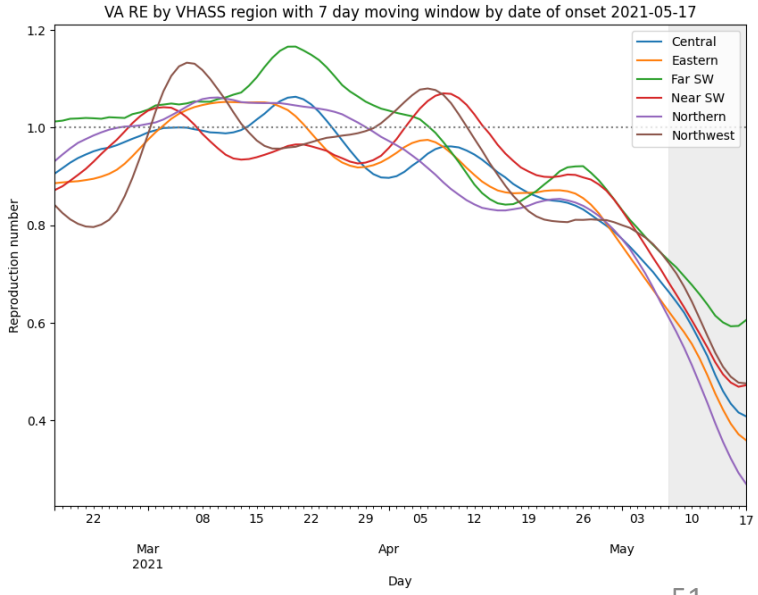
Supplemental Slides

Estimating Daily Reproductive Number

May 8th Estimates

Region	Date of Onset R_e	Date Onset Diff Last Week
State-wide	0.587	-0.038
Central	0.643	-0.040
Eastern	0.602	-0.073
Far SW	0.714	0.053
Near SW	0.658	-0.052
Northern	0.581	-0.061
Northwest	0.701	0.039





Methodology

- Wallinga-Teunis method (EpiEstim[1]) for cases by **<u>confirmation date</u>**
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Weekly Cases and Hospitalizations

Weekly confirmed cases

Week Ending	Adaptive	Adaptive-Fatigued Control	Adaptive-VaxOpt	Adaptive-Fatigued Control -VaxOpt
4/25/21	9,598	9,599	9,597	
5/2/21	9,747	9,767	9,850	
5/9/21	8,858	8,894	9,683	
5/16/21	8,048	8,086	10,150	
5/23/21	7,392	7,428	11,250	
5/30/21	6,713	6,561	13,152	
6/6/21	5,994	5,553	16,388	
6/13/21	5,365	4,521	21,163	
6/20/21	4,746	3,508	27,038	

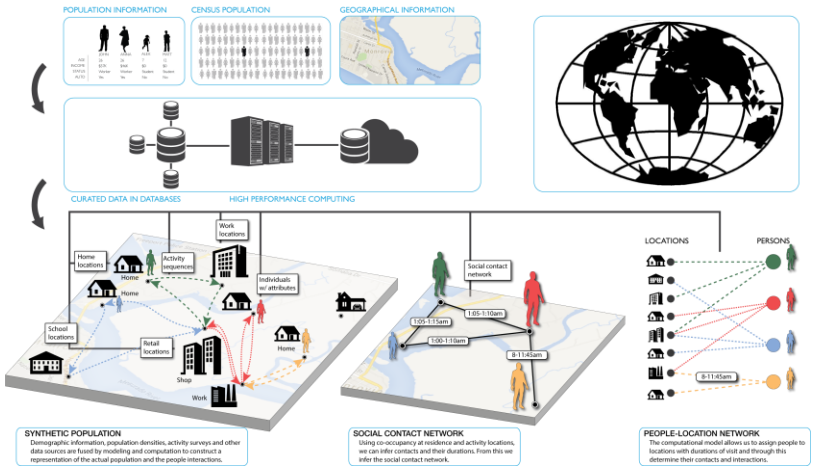
Weekly Hospitalizations

Week Ending	Adaptive-DominantB117	Adaptive-BestPast-DominantB117	Adaptive-Fatigued Control -DominantB117	
4/25/21	750	750	750	
5/2/21	659	659	666	
5/9/21	548	548	601	
5/16/21	451	452	575	
5/23/21	373	372	580	
5/30/21	302	292	609	
6/6/21	241	219	654	
6/13/21	196	159	707	
6/20/21				

Agent-based Model (ABM)

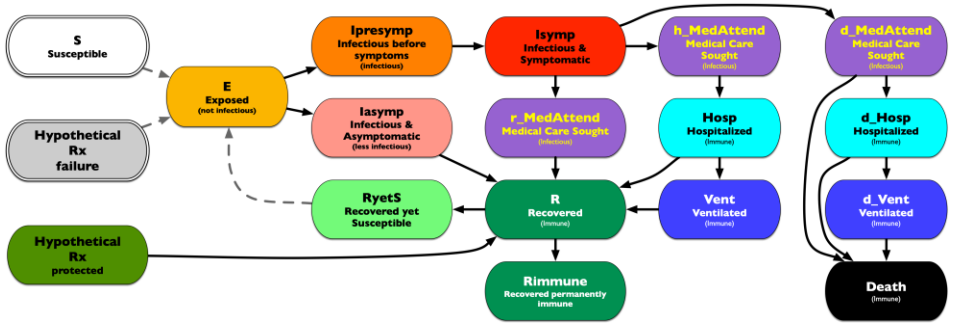
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



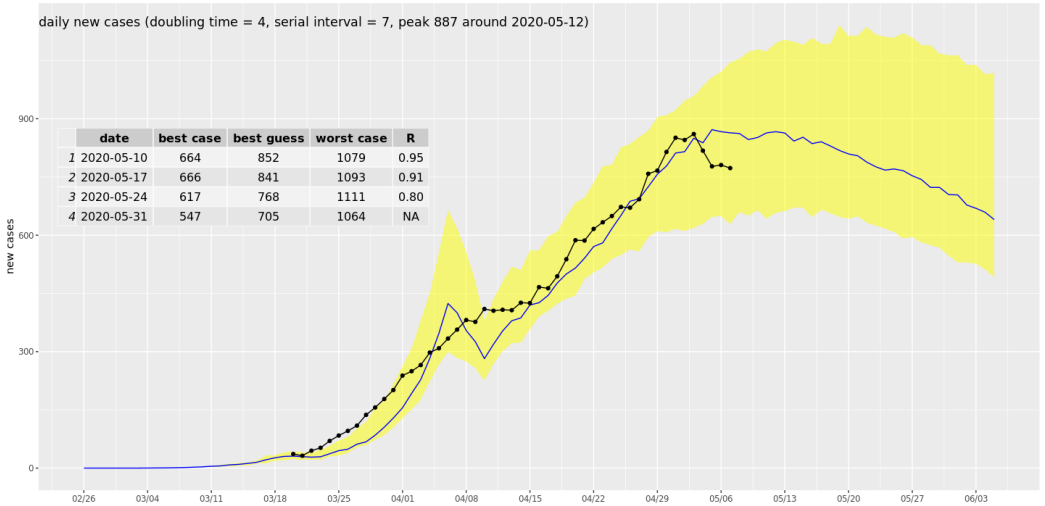
Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments

ABM Social Distancing Rebound Study Design

Study of ”Stay Home” policy adherence

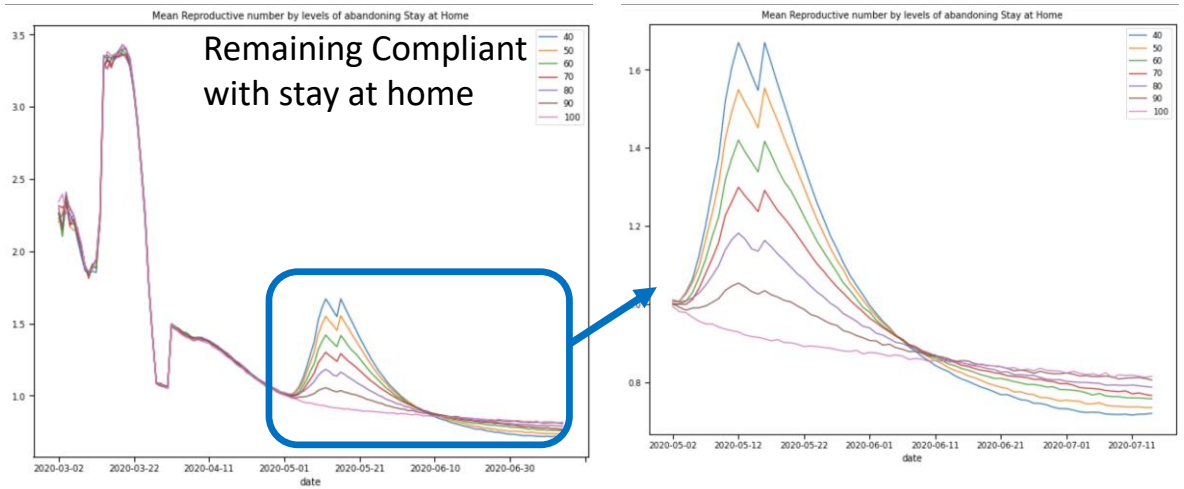
- Calibration to current state in epidemic
- Implement “release” of different proportions of people from ”staying at home”



	date	best case	best guess	worst case	R
1	2020-05-10	664	852	1079	0.95
2	2020-05-17	666	841	1093	0.91
3	2020-05-24	617	768	1111	0.80
4	2020-05-31	547	705	1064	NA

Calibration to Current State

- Adjust transmission and adherence to current policies to current observations
- For Virginia, with same seeding approach as PatchSim



Impacts on Reproductive number with release

- After release, spike in transmission driven by additional interactions at work, retail, and other
- At 25% release (70-80% remain compliant)
- Translates to 15% increase in transmission, which represents a 1/6th return to pre-pandemic levels